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Towards a Nickel Policy for the Province of Ontario



Ontario
Ministry of Natural Resources

MINERAL POLICY BACKGROUND PAPER No. 4

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NOTE:
This background discussion paper does not represent official policy and the views expressed herein are not necessarily the viewpoint of the Government of Ontario.

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Mineral Resources Branch
Division of Mines

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WORLD NICKEL ORE, CONCENTRATE AND MATTE MOVEMENTS IN 1977



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NOTE OF EXPLANATION: METRIC CONVERSION

Much of the data contained in this report is in converted metric units as recommended by the Ontario Interministerial Committee on National Standards and Specifications (Metric Committee). The tonne, commonly called metric ton (1 t = 1000 kg), is used throughout the text unless otherwise noted. Recommended conversion is 1 ton (short; 2000 lb) = 907.184 74 kg and 1 ton (long; 2240 lb) = 1016.046 908 8 kg.

Sources

Nickel is different from other base metals in one very important respect INFORMATION AND DATA ON NICKEL ARE MUCH MORE DIFFICULT TO OBTAIN. For example, for nickel there is no equivalent to organizations such as the International Tin Council, the Aluminum Association, the Copper Development Association, or the International Lead and Zinc Study Group, which dispense an exhaustive selection of papers, tables, diagrams and other data on those metals. Published statistics on nickel are quite skimpy.

IT IS RECOMMENDED THAT THE GOVERNMENT OF ONTARIO TAKE THE INITIATIVE IN PROPOSING TO THE NICKEL INDUSTRY AND CONCERNED GOVERNMENTS THAT A "WORLD NICKEL INSTITUTE" BE FORMED TO GATHER, STUDY AND PUBLISH OBJECTIVE INFORMATION ON NICKEL.

The authors would like to thank many individuals and organizations for their assistance and for much invaluable information published in numerous features and papers in a variety of journals over the years. Prominent among these are:

Commodities Research Unit Ltd., London, England
The Mining Journal, London, England
The Metal Bulletin, London, England
Roskill Information Services, London, England
Metallgesellschaft, A.G., West Germany
Imetal, France
Metals Week, U.S.A.
Department of Energy, Mines and Resources of the Government of Canada
Department of External Affairs of the Government of Canada
Government of Manitoba
Bureau of Mines, U.S. Government
INCO Metals Co. Division of INCO Ltd., Canada
Falconbridge Nickel Mines Ltd., Canada
Amax Nickel Inc., U.S.A.
J. Aron and Co., New York, U.S.A.
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Dr. G. Anders
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Foreword

The report "Towards a Nickel Policy for the Provice of Ontario" is the fourth in a series of studies prepared by the staff of the Mineral Resources Branch, Division of Mines, Ministry of Natural Resources. The series has grown out of the recognition that each of the major metal commodities produced in Ontaio is a unique entity with unique characteristics in a world-wide market. Nickel is the most important mineral mined in Ontario, in terms of aggregate value.

If government policies are to be formulated effectively, a thorough understanding of the relationships between the Ontario industry and the world nickel market on the one hand and the Ontario government and the Ontario industry on the other, is vital.

This report is an attempt to outline Ontario's role in a world-wide perspective and to achieve the understanding that will aid in the formulation of a nickel policy for this province.

The study provides background about the nickel industry as a basis for Ontario's policy formulation. In the study are not only statistical data, price behaviour and a review of the structure of the nickel industry, but also the authors' interpretations and analyses of this information.

Chapter 1 Executive Summary

ONTARIO IS THE WORLD'S LARGEST SINGLE SOURCE OF NICKEL. THE SUDBURY BASIN, AFTER 90 YEARS OF NICKEL MINING, IS THE OLDEST OF ONTARIO'S MAJOR MINING AREAS AND GENERATES ABOUT 60 PER CENT OF ONTARIO'S MINERAL WEALTH. (ESTIMATE FOR 1975-76).

INCO's investment in Sudbury is estimated to have a replacement value of over $4 billion. INCO spent over $1 billion in Canada (including Ontario) in the late 1960's and early 1970's to expand and modernize its facilities.

Nickel is one of several "most important" metals in the world and is likely to remain so. It is an exceedingly useful metal with wide applications and is one of the strategic metals for war. One quarter of the weight of a modern jet engine consists of nickel. Such engines as used in jet air liners contain over three-quarters of a ton of nickel per engine. Nickel uses pervade every aspect of modern life.

a) Canada (i.e. Ontario) had a near-monopoly on the supply of nickel to the world until 1950. Canada's percentage market share has greatly declined since 1950 and will continue to decline. Canada's nickel has been mostly of Class I grade, the purer form, but this is now being modified.

b) Other older nickel mining operations, i.e. Russia (mainly sulphide), Cuba (laterite) and New Caledonia (laterite), are being greatly expanded.

c) Greatly increased output of nickel is coming from a number of new mines, mainly laterite orebodies in the tropics, (high tonnage, modern technology open pit operations with cheap labour). These produce Class II lower price nickel which is used by the steel industry. This would seem to indicate that the selling price of nickel will stay in line with world commodity prices in general.

d) INCO Ltd., (INCO Metals Co. Division), *brought 2 new laterite nickel mines* on stream in 1977 in *Indonesia* and *Guatemala* — the company's first outside Canada.

e) INCO stated in July, and in December 1977, that employment is being cut back and some mines are being shut down in Ontario and Manitoba. It will reduce its number of employees in Canada. The ore production target for 1977 and 1978 has been lowered. Electrolytic nickel metal output has also been cut back drastically at INCO's Port Colborne, Ontario refinery. This appears to be a permanent measure. INCO production in other countries may also be affected in some way.

f) Falconbridge Nickel Mines Ltd. has *delayed the reopening of two Sudbury area mines* indefinitely. Officials said in July, 1977 nickel sales have not improved as anticipated.

On December 8, 1977, Falconbridge announced

1) suspension of production at the Lockerby mine;
2) extension of the 1978 summer shutdown to seven weeks;
3) further reduction of jobs in the Sudbury Basin operations;
4) the improved smelter will use only one electric furnace in 1978.

1978 output from INCO and Falconbridge at Sudbury will be about two-thirds of rated capacity.

g) Greatly increased capital cost of new mining projects has emerged as a development problem, compounded by the financial burden of unsold nickel stocks.

h) Greatly increased costs of mine production in Canada etc. have developed, with a *narrowing margin of profit* on mining particularly in underground mining.

i) This squeeze was characterized by the early 1977 cuts in world nickel prices, the first major price cuts in dollar terms since 1965. World nickel consumption fell 22 per cent in 1975 from 1974 and "stockpiling" by mine producers masked the effect of this decline until late 1976 and early 1977.

j) INCO is likely to continue its Sudbury operations at some level for several decades. There are many reasons, but one powerful one is that the Sudbury Basin ore reserves are the most valuable single asset the company has and another is that it is a prime source of Class I nickel, needed for INCO's wholly owned rolling mills in the U.S.A. and the U.K., taking about 25,000 tons of nickel a year.

k) INCO as a member of a consortium with a U.S. $40 million project, is spending money on sea bed nickel mining research and the necessary metallurgy. It may prove to be a most valuable investment. INCO has two reasons to be concerned about sea bed mining. One is its obvious self-interest. INCO would prefer not to see its land-based Canadian nickel resources jeopardized in any way. However, if ocean mining is authorized by the United Nations or by the U.S.A. unilaterally, INCO, a major world producer of nickel, copper etc., does not want to be dealt out.

1.1 Conclusions

CONSUMPTION

1) World nickel consumption growth should average at best between 3 and 4 per cent a year through 1985.

2) Further to such a moderate forecast of the nickel consumption growth rate, (compared to the apparent historical long term growth of over 6 per cent), a sharp downturn in total 1978 nickel consumption is still possible.

3) Mine producers without consumer market ties for all their product will be hard hit in the lean years. For example, Falconbridge Dominicana output should have one slight advantage because of nickel-consumer Armco Steel Corporation's investment in the project. The same may not be true for Falconbridge's electrolytic production in Norway which is largely dependent on Ontario mineral feedstock, and is not financially connected to any major consumer.

PRODUCTION

4) Excess mine capacity will persist into the early 1980's, considering the prognostication for lower levels of future world consumption. This suggests that some marginal Western World nickel projects will be closed down and other measures taken to reduce world production, in line with consumption. This includes the possibility of further production cutbacks at Sudbury.

   However, it can be assumed from past experience that Comecon and some of the developing countries will not defer expansion of their nickel output. This will add to excess production and the pressures on Western producers.

COMPETITION

5) Comecon and developing countries will continue to increase their share of the world nickel market and the effect of this will be to further soften world nickel prices.

6) The price war between the major mine producers in the West may continue in 1978 and probably 1979.

7) World stockpiles of nickel, as with world stockpiles of copper, have grown to excessive levels. In the case of nickel, there is very little information available to determine precise levels, but it is apparent that they reflect the sharp drop in demand and the attempt by producers to ride this out without cutting output. Hence it is evident that mine production cutbacks now are necessary. Such nickel production cutbacks will help to reduce industry stockpiles a little.

8) For at least 30 years, the nickel industry of the West has been somewhat protected by governments, largely in the form of contracts with the U.S. and other governments for nickel for strategic stockpile and military purposes. The latter half of the 1970's and the 1980's however could be characterized by a marked reduction in such protectionism, thus making even a moderate growth in world demand difficult to achieve.

9) Nickel production from sea-bed nodules may be assumed to start before 1985. Whether or not sea-bed production of nickel-copper nodules commences in the early 1980's or 1990, it remains a threat to the future of Ontario nickel mines. If world consumption grows at a fast rate, Ontario may not be as drastically affected. (It is a big "if"). However, it appears that, over this time-frame, the consumption growth for nickel should be much lower than it has been in the last 30 years and, therefore this provides the Government of Ontario with a reason for great concern.

ACTIONS BY GOVERNMENTS

10) There never has been any long term shortage of nickel. Resources from areas of the world such as Canada, Russia, New Caledonia and Cuba have generally been sufficient to meet foreseeable demand for periods much greater than 25 years into the future. Therefore, Western governments must strive to be competitive in making the economic environment attractive to multi-nationals and others.

MARKET SHARE

11) While Canada, i.e., Ontario, had a near monopoly on the supply of nickel as early as 1918 and as late as 1950, Canada's market share has greatly declined since and will continue to do so. It may, however, remain the largest single nickel-producing nation. If the rate of return on INCO's new projects in Indonesia or Guatemala were to prove much greater than that of Ontario or Manitoba, production cuts will continue in Canada rather than overseas and the situation would be aggravated by any further increases in taxes in Canada, or by any other measures that lower after-tax rates of return.

COSTS

12) The estimated production cost of marginal mines increased from about U.S. $2.50 per pound of nickel in 1975 to $3.75 at end-1977, i.e. far above the present and foreseeable market price for nickel. Both capital and operating costs of new mining projects in the nickel industry have escalated appreciably. As with the copper industry, nickel may in some ways become a burden to be carried largely by market economies, owing to the inflexible expansion in Eastern Bloc countries such as Russia and Cuba and in developing countries. As with most peaks and troughs in economic activity, mining companies are affected simultaneously by product price cuts as well as production cost inflation. This means that, at the end of a long very strong inflationary growth period, the mineral industry demonstrates an extremely poor return on investment, much worse than manufacturing companies.

PROFITABILITY

13) It now appears likely that so-called "excess" profits in peak years of high world prices, (the most recent peak year was 1974), will no longer compensate for the lean years which we foresee over the medium term. The "golden" years for Canadian nickel profitability were from 1932 to 1956 and such remarkable profits on nickel output may never again materialize.

TAXATION

14) It would seem prudent at this juncture to avoid any increases in total taxation on the Canadian nickel industry whether from the federal, provincial or municipal level. Similarly, environmental restrictions should be minimized, as part of a comprehensive plan to remove as many hurdles as possible which hinder mining growth.

VARIOUS FORMS OF NICKEL

15) The world steel industry has probably been affected more than other parts of the economy by the current economic adjustments to the inflationary boom of the last two decades. As a result intermediate Class II nickel raw materials such as oxide, sinter and ferro may be subject to much more of a downturn than refined nickel products. This would suggest again a better outlook for sulphide orebodies which are more amenable to exploitation for pure nickel than the laterites. However, INCO's carbonyl pellet process at Clydach, Wales, now being modified, circumvents this obstacle and allows the company to use lateritic matte as charge for producing a refined nickel product. FOR THE FIRST TIME SINCE 1900, CLYDACH IS NO LONGER ENTIRELY DEPENDENT ON CANADIAN NICKEL MATTE. Nonetheless, sulphide ores are easier to concentrate and hence they save on transport costs, fuel and smelter utilization.

OREBODIES

16) Laterite orebodies are uniform in grade since they are a result of weathering of low grade nickel bearing rock. The ore is unconsolidated, near surface and hence readily amenable to open pit development.

17) Sulphide orebodies are almost invariably massive consolidated material with a greater variation in grade. They are, therefore, amenable to both underground (such as cut and fill, blast hole stoping, underhand cut and fill etc.) and open pit development.

18) With Sudbury type orebodies, it is possible to select a mine plan which extracts the high grade ore, leaving the lower grade ore for years when prices and the general economic environment are more favourable. Under these assumptions, one can visualize a case for a producer who has both sulphide and laterite orebodies (e.g. INCO and Falconbridge), reducing laterite output.

19) Counterbalancing these observations is the fact that some of the newer laterite deposits have higher production rates and therefore their labour costs and the unit cost of ore production are much lower than, say, Sudbury-type operations in which the mines feeding into a centralized mill are numerous.

SUGGESTION

20) The establishment of a battery production facility by ESB Inc. in Sudbury or Port Colborne would help to alleviate some of the unemployment problems faced by its parent, INCO Ltd.

1.2 Policy Alternatives

THE OBJECTIVE OF ONTARIO MINERAL POLICY

THE GOVERNMENT OF ONTARIO IS COMMITTED TO THE OBJECTIVE OF SECURING FOR THE PEOPLE OF ONTARIO THE MAXIMUM ECONOMIC BENEFIT FROM ONTARIO'S MINERAL RESOURCES IN TERMS OF JOBS AND INCOME THROUGH THE INVESTMENT OF PRIVATE CAPITAL IN A HEALTHY AND GROWING MINERAL SECTOR.

The Province's mineral policy thrust is generally directed towards:

i) MAINTAINING ONTARIO'S LEVEL OF MINE PRODUCTION THROUGH THE ENCOURAGEMENT OF PRIVATE-SECTOR INVESTMENT IN EXPLORATION AND MINE DEVELOPMENT; AND

ii) INCREASING THE LEVEL OF REFINED PRODUCTION IN ONTARIO BY ENHANCING THE INVESTMENT CLIMATE FOR REFINING CAPACITY IN ONTARIO.

The aims of the Province's mineral policy are in harmony with some of the following broad policy objectives outlined in "Towards a Mineral Policy for Canada", such as

a) "STRENGTHEN THE CONTRIBUTION OF MINERALS TO REGIONAL DEVELOPMENT";

b) "REALIZE OPPORTUNITIES FOR FURTHER MINERAL PROCESSING".

MINERAL POLICIES, AND OTHER POLICIES IMPACTING ON THE MINERAL SECTOR, BOTH FEDERAL AND PROVINCIAL, SHOULD BE STABLE OVER THE LONG-TERM AND SHOULD NOT BE SUBJECTED TO YEAR-TO-YEAR BUDGETARY MODIFICATIONS. IF INVESTMENT IN EXPLORATION AND MINERAL DEVELOPMENT IS TO BE MAINTAINED AT ITS PRESENT LEVEL, LET ALONE INCREASED.

If government policies are to be formulated effectively, a thorough, in-depth understanding of the relationships between the Ontario industry and the world market on the one hand, and between the Ontario Government and the Ontario industry on the other, is of vital importance.

IT MUST BE EMPHASIZED THAT GOVERNMENT POLICIES CAN BE EFFECTIVELY DIRECTED ONLY TOWARDS THE REDUCTION OF RATHER LIMITED COSTS, RISKS AND UNCERTAINTIES.

THERE ARE PROBLEMS OVER WHICH THE GOVERNMENTS OF MOST MINE OUTPUT COUNTRIES HAVE NO CONTROL SUCH AS COMMODITY PRICES AND WORLD WIDE CYCLICAL MOVEMENTS.

SINCE THE REVENUES FROM METAL SALES AT WORLD PRICES ARE CONSEQUENTLY BEYOND ONTARIO GOVERNMENT CONTROL, POLICY CAN BE AIMED ONLY AT REDUCTION OF COSTS AND RISKS.

THE GOVERNMENT OF ONTARIO CAN BE MOST EFFECTIVE IN ALTERING SUCH AREAS AS PROVINCIAL TAXES, REGULATORY DELAYS, ENVIRONMENTAL STANDARDS AND HEALTH AND SAFETY REGULATIONS. FOR TAX LEGISLATION TO BE EFFECTIVE, OTHER PROVINCIAL POLICIES REGARDING ENERGY AVAILABILITY, LABOUR SUPPLY, INFRASTRUCTURE AND ENVIRONMENTAL PROTECTION SHOULD BE STRUCTURED SO AS TO COMPLEMENT THE GOALS RATHER THAN CONFLICT WITH THEM.

WORLD-WIDE INFLATION, LABOUR COSTS AND STRICT ENVIRONMENTAL STANDARDS SERIOUSLY INTERFERE WITH ATTAINING A HEALTHY LEVEL OF PROFITABILITY. IN PARTICULAR, *THE PLANNING AND FINANCING OF NEW MINES AND REFINERIES REQUIRE A STABLE TAX ENVIRONMENT, FREE OF POLITICAL UNCERTAINTY,* OR EQUIVALENT RAPID RETURN OF CAPITAL.

1.3 Nickel Policy Proposals

1) THAT THE GOVERNMENT OF ONTARIO TAKE THE INITIATIVE IN PROPOSING TO THE NICKEL INDUSTRY AND CONCERNED GOVERNMENTS THAT A "WORLD NICKEL INSTITUTE" BE FORMED TO OBTAIN, STUDY AND PUBLISH A WIDE RANGE OF OBJECTIVE INFORMATION ON NICKEL ON A CONTINUOUS BASIS, AS IS DONE BY THE SMALL, LOW COST BUT SUCCESSFUL SILVER INSTITUTE.

2) ENCOURAGE THROUGH SPECIAL ONTARIO INCOME AND MINING TAX ADJUSTMENTS, THE ADAPTATION AND USE OF CURRENTLY IDLE NICKEL REFINING CAPACITY IN ONTARIO AND ALBERTA TO REFINE PART OR ALL OF THAT SIGNIFICANT PROPORTION OF ONTARIO'S MINE OUTPUT OF NICKEL WHICH STILL GOES TO WALES AND NORWAY IN SEMI-REFINED FORM FOR REFINING, SO AS TO CREATE JOBS IN CANADA. IT IS UNDERSTOOD THAT THE PRESENT ALBERTA REFINERY PROCESS DOES NOT RECOVER PRECIOUS METALS.

3) ENCOURAGE THE REFINING IN ONTARIO OR CANADA OF THE BY-PRODUCT PLATINUM GROUP METALS (P.G.M.) FROM ONTARIO NICKEL MINES WHICH NOW ALL GO ABROAD FOR REFINING TO METAL. ONTARIO IS THE WORLD'S THIRD LARGEST SOURCE OF PLATINUM GROUP METALS, BUT AFTER 50 YEARS STILL HAS NO P.G.M. REFINERY BASED ON PRIMARY FEED. THIS CHANGE WOULD CREATE NEW JOBS IN NORTHERN ONTARIO OR ELSEWHERE IN CANADA.

4) THE ENCOURAGEMENT OF CUSTOM AND TOLL WORK IS DESIRABLE SINCE JOBS ARE CREATED AND MAINTAINED. ONE INCENTIVE MIGHT BE TO ALLOW THE DEDUCTION OF SUCH COSTS IN DETERMINING THE MINING TAX OF AN INTEGRATED PRODUCER. THIS WOULD INCLUDE CUSTOM OR TOLL CONCENTRATING, SMELTING AND REFINING OF NICKEL ORES, CONCENTRATES, MATTE AND OTHER RAW MATERIALS. AT PRESENT, INTEGRATED PRODUCERS CAN DEDUCT ONLY COSTS OF REFINING NICKEL FROM THEIR OWN MINES.

   THIS OPTION HAS THE ADVANTAGE NOT ONLY OF ENCOURAGING FURTHER PROCESSING AND MAINTAINING JOBS IN SUCH FACILITIES, BUT ALSO OF PROVIDING INDIRECT EXPLORATION INCENTIVES VIA REDUCTION IN COSTS TO JUNIOR MINING COMPANIES. OTHER INCENTIVES MAY ALSO BE NECESSARY IN ORDER TO MAKE THIS OPTION ATTRACTIVE TO THE INTEGRATED PRODUCER.

5) INTENSIFY DIVERSIFICATION BY A SPECIAL EXPLORATION CREDIT UNDER THE MINING TAX IN YEARS OF LOW PROFITABILITY. MATCHING FEDERAL INCENTIVES ARE DESIRABLE IF THE MAXIMUM EFFECT IN EXPLORATION ACTIVITY IN ONTARIO IS TO BE ACHIEVED.

6) INTENSIFY DIVERSIFICATION OF THE SUDBURY MANUFACTURING BASE BY ENCOURAGING THE IMPORTATION OF INCO SUBSIDIARIES' TECHNICAL AND NICKEL MANUFACTURING EXPERTISE ACQUIRED THROUGH RECENT DIVERSIFICATION, NOT NOW EMPLOYED IN CANADA, FOR THE PURPOSE OF CREATING NEW INDUSTRY AND EMPLOYMENT IN SUDBURY.

7) ENCOURAGE CONSIDERATION OF DIRECT REDUCTION OF NICKEL-BEARING PYRRHOTITE GENERATED IN THE NICKEL SMELTING PROCESS AND UTILIZATION OF THE IRON PELLETS IN A MINI-STEEL PLANT IN SUDBURY, THEREBY CREATING NEW INDUSTRY AND EMPLOYMENT — PERHAPS 700 JOBS.

Chapter 2 Nickel Supply and Demand Picture

Western World Only, Estimated by Sumitomo

	1977
Inventories of *finished nickel ready for sale*, January 1, 1977 (Sumitomo estimate)	220,000 metric tons minimum
Mine Production, 1977	580,000 metric tons
Sea Bed Production	nil
Imports into the West from Eastern Bloc, 1977	20,000 metric tons
TOTAL SUPPLY, 1977	820,000 metric tons
TOTAL DEMAND, 1977	up to 550,000 metric tons
Inventories of finished nickel at December 31, 1977, estimated by Sumitomo at around	270,000 metric tons
(an *increase* of about 50,000 metric tons during 1977)	

Source - Sumitomo

In the case of nickel, one should look carefully at metal production-consumption patterns for the last 5 years. Mine production exceeded consumption in 1972 by 8%; 1973 by 3%; 1974 by 2%; 1975 by some 29% and 1976 by about 17%.

2.1 Balance of Consumption and Production of Nickel
(excluding stocks of finished nickel)

Nickel ore deposits are for the most part located inconveniently throughout the globe in relation to the per capita consumption of the major markets. This is a contrast with copper, for instance, of which there is considerable domestic production in many of the major consuming nations. However, taking the U.S.A. and Canada together, for example, gives a more balanced regional picture for North America.

MAJOR CONSUMING AREAS

	1960	1976
	metric tons	
JAPAN		
Consumption	17.6	115.0
Domestic mine production	—	—
Net	**17.6**	**115.0**
EEC (Including U.K. & Denmark)		
Consumption	74.5	149.4
Domestic mine production	—	—
Net	**74.5**	**149.4**
U.S.A.		
Consumption	98.1	150.0
Domestic mine production	12.8	12.6
Net	**85.3**	**137.4**

MAJOR PRODUCTION AREAS

	1960	1976
	metric tons	
CANADA		
Mine production	194.6	262.5
Consumption	4.4	11.5
Net	**190.2**	**251.0**
AUSTRALIA*		
Mine production	54.1	223.4
Consumption	2.5E	4.3
Net	**51.6**	**219.1**
EASTERN BLOC**		
Mine production	76.3	179.3
Consumption	75.0E	173.5
Net	**1.3**	**5.8**
AFRICA		
Mine production	2.9	51.2
Consumption	2.0E	5.0
Net	**0.9**	**46.2**
OTHER EUROPE***		
Mine production	2.1	23.2
Consumption	1.4E	2.0
Net	**0.7**	**21.2**
OTHER AMERICA****		
Mine production	0.1	26.6
Consumption	1.4E	5.6
Net	**(1.3)**	**21.0**

E — Estimated by Mineral Resources Branch, Ontario.

* — Including Australia, New Caledonia, Burma, Indonesia and Philippines.

** — U.S.S.R., Eastern Europe, Cuba and other mainland Asian countries.

*** — Finland, Greece and Norway.

**** — Mexico and Central America, Dominican Republic, Brazil.

Source: Metallgesellschaft, op. cit.

Perusal of the above table leads to the conclusion that only the Eastern Bloc and the U.S.A.-Canada region are self-sufficient as consuming areas. The great powers in the West generally have to import this strategic metal over water, except of course the U.S. nickel imports from Canada.

2.2 World Demand for Nickel
(All Countries) — Summary

In 1978, world supplies of nickel from mines will continue to exceed demand, unless there is a miraculous world economic recovery or a major war. AMAX Inc., U.S.A., forecast that "Western World" nickel consumption in 1978 will be at about the record level of 1974.

CONSUMPTION OF REFINED NICKEL*, WORLD, ESTIMATED
(Excluding recovery from scrap)
(includes Eastern Bloc)

(metric tons)

1970	1971	1972	1973	1974	1975e	1976e	1977f
576,000	526,000	580,100	655,200	707,200	574,500	665,700p	687,000+

n.b. 90 per cent of the variation in nickel consumption is attributable to stainless steel.

* **Metallgesellschaft**
"Consumption" of metals has, as a rule, been calculated according to the formula: Production + imports - exports ± changes in stocks (as far as these are given). It represents, therefore, the quantity of crude metal available for consumption without considering whether the products manufactured from it are consumed at home or exported. A number of countries now compute either deliveries of crude metal to consumers or the output by works of the first processing stage. In these cases Metallgesellschaft has used the figures thus obtained.

\+ For "Western World" component — 3 per cent above 1976.

p Preliminary

e Estimate

f Forecast

Firm figures for nickel consumption in the Western World are impossible because analysis of the statistical material available reveals large disparities which are mainly due to a lack of uniformity in import, export and ore definitions and to the *absence of firm figures from the second most important supplier, Russia* and from other Comecon countries. Estimates are based on the most reliable sources available, but are *exclusive of "secondary" supply,* which is acquiring increasing importance in world availability of refined nickel metal.

MAJOR USES OF NICKEL AND ITS ALLOYS

Primary Raw Material	Intermediate Product	Application
Nickel pellets, Nickel powder	Nickel catalysts — powder and flakes — mixtures with aluminum — mixtures with magnesium	— aging liquors — bleaching, drying of oils — sulphur compound removal in coal gas — chemical and petrochemical production — alcohol production
Nickel salts	Nickel sulphates, chlorides, carbonates, hydroxides, oxides	— electroplating — batteries — catalyst production
Nickel powders	Nickel and nickel alloy powders	— sintered carbides (e.g.) tungsten carbide — batteries — magnetic alloys — controlled expansion alloys — magnetostrictive alloys (e.g.) sonar and ultrasonic devices
Pure Nickel — Cathode, Briquettes, Pellets, Powder	Ribbon, strip, tube, bar, sheet	— electronics — cathodes bases, grids — T.V. tubes — coinage — jewelry of gold filled — rolled gold plate — white gold alloys — controlled expansion alloy applications (e.g.) temperature controls
Pure Nickel cathodes, and Anodes	1" Squares, rounds, billets, pillows, cast shapes, of nickel	— electroplating of many consumer and industrial products usually with chromium final coating. (For corrosion resistant properties and decorative applications.)

Primary Raw Material	Intermediate Product	Application
Nickel (all primary forms) Class I and Class II	Nickel as an alloy in steels for construction and machinery	aircraft parts aerospace equipment machinery parts gears, impellers wear parts - construction steels for vessels bridges, buildings cryogenic vessels
Nickel (all primary forms) Class I and Class II	Nickel as an alloy in cast iron and cast steels	machinery parts equipment parts sporting equipment durable consumer products, valves, pumps, gears transportation equipment engines of all kinds mining equipment grinding balls - wear parts
Nickel (all primary forms pure and impure) Class I and Class II	Nickel as an alloy (usually 8% nickel or higher) in stainless steels	automotive trim, wheel covers, etc. architectural uses, railings, curtain wall, mullions, elevators and escalators chemical and petrochemical production, vessels, pumps, valves, pipe and tubing, filters, heat exchanger, etc. springs, spinnerets food and drug production — vessels, pumps, conveyors restaurant equipment operating and X-ray equipment surgical instruments and implants - utensils and cutlery medallions, coins, tokens aircraft parts - railroad cars and automotive trucks for corrosive liquid transportation and dairy products - pulp and paper mill equipment fasteners — bolts, nuts, etc. welding rods
Pure Nickel — cathodes, briquettes, pellets	Nickel as an alloy in copper and its alloys; copper in nickel alloys	coinage springs, valve parts, bearings - corrosion resistance uses with sea water — pumps, etc., heat exchanger tubing, tube sheets, pumps architectural uses ship propellers (nickel, aluminum, bronze) - marine hardware cutlery (silver plate) non-magnetic applications brazing alloys electrical ground rods (lightning rods) - many uses in petroleum refineries because metals will not generate a spark - thermocouples
Pure Nickel Cathodes, pellets, briquettes, powder	Alloys of Nickel and iron, ferrous super alloys	automobile pistons aerospace engine parts - gas turbines glass to metal seals in electronics bimetallic strip springs tuning forks - clock parts length standards telephonic and radio frequency circuits

Pure Nickel — pellets, cathodes, and powder, briquettes	Alloys with aluminum	permanent magnets — automotive engine parts
Pure Nickel pellets, cathodes and powder, briquettes	Nickel — chromium alloys — cast and wrought and nickel, chromium iron alloys	— thermocouples electrical resistance alloys (stove elements) — heat treatment furnaces and parts — petrochemical refining (reformer tubes) — jet-engine parts — nuclear plant parts (tubes, heat exchangers, metal seals) — high corrosion, high temperature bellows and springs — aerospace craft outer skin
Pure Nickel — pellets, cathodes and powder, briquettes	Nickel, molybdenum iron alloys	— special applications for corrosion resistance uses in acids and in high temperatures
Pure Nickel — pellets, cathodes and powder, briquettes	Nickel, cobalt, iron alloys	— glass to metal seals (e.g.) heart pacemaker
Pure Nickel - pellets, cathodes and powder, briquettes	Nickel, chromium cobalt alloys	— high temperature, high strength applications in jet engines, valve parts, stationary power plant engines — steam power plants
Nickel Powder	Ceramets - nickel with aluminum oxide	— long stress rupture life at high temperature — jet engine and propulsion engines
Nickel Powder	Nickel mixed with other metal powders of iron, copper, etc.	— powder metal sintered parts — gears — metal seals — valve seats — golf club heads — valve trim — pump parts - auto engine parts — welding and brazing rods and wire — wear resistant coatings on wear parts

2.2.1 CONSUMPTION OF NICKEL

The impure Class II nickel, (i.e. utility shot and pig, ferronickel, etc.) is supplanting the purer, more expensive Class I nickel in the major range of uses. There was a time not too many years ago when a large part of the nickel used in the manufacture of stainless steels was added in the form of pure (Class I) nickel metal.

On the one hand, the negative effect may be seen in the closing down of the (Class I) pure nickel cathode refining line at Port Colborne, Ontario, (former capacity, 70,000 tons of nickel a year), at the close of 1977, in the 1978 cuts in mine output in Canada by INCO and in the 1976, 1977 and 1978 reductions in Ontario mine output by Falconbridge (whose refinery in Norway produces from Ontario feed mainly pure nickel cathodes at present) — in the refinery cases because they were unable to sell all of the nickel cathodes they have both been producing.

On the other hand, the positive effect may be seen in the welter of new mines opened since 1971 which produce the lower quality Class II nickel, (with a relatively small number of exceptions in Australia). These new mines – Falconbridge in the Dominican Republic, the French in New Caledonia (expansion), Greece, Cuba, Queensland, (Australia) and recently INCO in Indonesia and Guatemala — have taken a large part of the market away from INCO's and Falconbridge's Canadian pure nickel output and from some Australian output. Other new mines produce matte or concentrates which can be converted to either Class I or II nickel.

The reason the world prefers to take new Class II production where possible, (supplanting a large amount of Class I nickel), stems from price advantage and recent technological advances, such as: *A Revolution in both Furnace and Vessel Technology.*

USE OF NICKEL

Nickel is primarily used in association with other elements in some 3,000 alloys to impart strength, toughness and corrosion resistance at normal temperatures as well as at high and low temperatures. It is also used in an unalloyed state, particularly as a plating material. Pure nickel is also widely used in the world's coinage systems.

SUMMARY OF USES

Nickel-containing materials find application in the automotive, aerospace, energy conversion, marine, transportation, machinery, electronics, chemical and petroleum industries, as well as in consumer products. Typical applications of nickel stainless steel are in *building materials, rapid transit* and *railway cars, food handling equipment,* and chemical fertilizer manufacturing and handling equipment. The automotive industry is the biggest user of *nickel plating,* especially *for automobile bumpers.* The high-nickel alloys are used for components of the *gas turbine engine, nuclear reactors* and other applications where resistance to heat and corrosion is essential. Copper-nickel alloys have numerous commercial seawater applications, notably in *shipboard piping* and *desalination plants.*

There is currently *no completely satisfactory substitute* for nickel in any of its major uses *at comparative costs*. Over 90 per cent of nickel used is in a metal form, principally alloys. Substitution is still an objective pursued vigorously by many companies. THERE IS HOWEVER APPARENTLY NO TREND TO REPLACE NICKEL IN STAINLESS, SUPER-ALLOYS, ETC. WITH OTHER MATERIALS, DURING THE NEXT 20 YEARS.

1) Nickel is used in non-ferrous and steel alloys, e.g. *stainless steels, armour plate, nickel bronzes, coinage,* corrosion-resisting and heat-resisting alloys, (as in main jet engine components). Some nickel steels are:

   a) Nickel-chromium alloy steels (Stainless Steels). Nickel strengthens the alloy and increases its toughness. High nickel-chromium steels are indispensable in equipment for many chemical and *food* processes, paper manufacturing and *petroleum* refining, and for *surgical instruments* and *hospital equipment*. Iridium implants in human female breasts to treat cancer, rather than remove the whole breast has about a 75% successful survival rate after ten years. For large tumours, the radioactive short-lived man-made isotope Iridium 192 is inserted into hollow *stainless steel tubes* embedded in the breast which prevent emission of dangerous ionizing beta rays but allow escape of the high-energy gamma rays that destroy the tumour.

   b) Nickel steels are utilized in chemical equipment for sub-zero operation, since they resist embrittlement by cold.

2) Used in electrowinning: also in the electroplating of nickel, as on automobile bumpers underneath the chrome deposit.

3) Used in chemicals and in catalysts, as in the production of *margarine*, and in pigments, dyes, paints, varnishes, batteries and insecticides. Nickel salts are antiseptic. They arrest fermentation and stop the growth of certain plants.

4) *Nickel for Fuel Cells*
   The fuel cell is a device for generating electricity directly and continuously from an electro/chemical reaction inside a "cell" or container. Nickel plate electrodes were used by the British inventor, Francis "Tom" Bacon, in the first successful demonstration of a fuel cell in 1959, mixing the two common gases, hydrogen and oxygen. Bacon received some technical help from INCO. The three fuel cells which provided the electricity in each of the "Apollo" spaceships for guidance, communications, air conditioning and lighting during the 14-day flights to the moon were developed by Pratt and Whitney, the U.S. licensees of Bacon's patents.

MAIN MARKETS FOR NICKEL

U.S.A., Western Europe and Japan continue to be the principal consumers of nickel. U.S. consumption in 1974 was 194,500 metric tons and in 1975 136,000 metric tons. U.S.A., the largest consumer, took 99,992 tons of nickel from Canada in 1975. Japan consumed about 90,000 metric tons in 1975.

2.2.2 HISTORICAL CONSUMPTION AND GROWTH TRENDS

NICKEL STEELS

Nickel was first incorporated in steels by the Frenchman, Marabeau, and the properties were described by the Scot, James Riley in 1889, not long after the discovery of nickel deposits at Sudbury, Ontario. The United States Navy adopted nickel steel for armour-plate in 1891. Armour plate typically contains 3.75 to 4 per cent nickel.

STAINLESS STEELS

Between 1912 and 1914, Harry Brearley of Sheffield, England investigated a series of steels containing between 9 and 16 per cent of chromium. Similar work was done at that time by Schoeller-Bleckmann of Austria. From these "rustless" steels were developed the familiar "stainless" steels. Strauss, associated with Krupp in Germany, investigated certain steels containing both nickel and chromium between 1912 and 1914. The most useful and most familiar of the stainless steels is "18/8" (containing 18 per cent chromium and at least 8 per cent nickel), developed later. THESE STAINLESS STEELS NOW CONSTITUTE THE LARGEST SINGLE USE FOR NICKEL.

GROWTH IN WORLD DEMAND

Demand for nickel is cyclical, typically in 5 to 7 year spans. 5 to 6 per cent was the apparent *average* growth rate per year over the last two or three decades.

Worldwide, decision-makers — both in industry and government — were lulled into complacency during the long period of exceptionally rapid cumulative economic growth, roughly from 1950 to 1970. Extending trends forward, they started to think that these consumption growth rates would go on forever. Plans for production capacity expansion in the mineral sector were made accordingly and were implemented. What was generally forgotten was the fact that the 20-year rapid growth was due to an unusual coming together of developments in different fields.

1) The industrialized Western nations catching up from World War II levels to U.S. levels of per capita metals consumption or living standards.

2) Growth in U.S. and other defence spending: Korea, Cold War, Vietnam.

3) Inflationary over-expansion of capital goods industries throughout the Western world.

4) An extended period of very low real interest rates attributable to expansionary economic policies in industrialized Western nations.

THE 10 YEARS, 1967 - 1977

COMPLETELY NEW FACTORS AROSE IN THIS DECADE:

Over-optimistic rates of growth in consumption of nickel were a feature of earlier "forecasts" and a direct result of these was a heavy investment in new nickel mining production in the late 1960's and early 1970's, e.g. Australia, Dominican Republic, Philippines, Botswana, Indonesia, Guatemala, etc. The supply shortage that began in the free world's nickel markets in 1966 eased considerably in the latter part of 1970 and came to an end in early 1971 as a result of rising production and a softening of the economies — and thus of the demand for nickel — in the major nickel-consuming countries.

90 per cent of the variation in nickel consumption from year to year is now attributable to stainless steel production — which can utilize cheaper ferro-nickel etc. from the tropics — particularly since the development of the A.O.D. vessel, (see chapter 12.3).

During the 6-year period, 1969-74, (roughly the years of the Vietnam conflict), U.S. consumption of nickel grew at about 10 per cent per year, but since then that trend has flattened, so that for the short period ending in 1977, the growth rate moderated to about 3% a year in the U.S.A.

Nickel is one of a small number of primary metals for which demand *in time of war* escalates at a much higher rate than the growth of the overall Western economy. When a major conflict such as Vietnam has been terminated, (Spring of 1975), overall World demand for nickel drops noticeably.

Defence-related "set-asides" of nickel in the U.S.A. began in August, 1966.

Stockpiling of nickel by the U.S. government had been completed before 1966 and was all sold off by 1972. Most of the U.S. stockpiling of nickel took place in the 1956-1965 period, having been set up following the Korean conflict.

The producers' price for nickel in dollar terms rose steadily from 1963 through 1976 in healthy increments. Because it has become a much more expensive metal than it was, substitution in industrial applications increased — i.e. less nickel in alloys etc. — and newly developed low-nickel or nickel-free alloys could become highly competitive.

The three years of surplus supply of nickel, (1970 through 1972), were followed by an approximate balance between supply and demand which was achieved in the second half of 1973.

Very large accumulations of unsaleable refined nickel stockpiled by industry on the surface became a prominent feature of the years 1971 and 1972, as well as 1975, 1976 and 1977.

In 1974, demand for nickel strengthened briefly in the first half and ferro-nickel continued to increase its share of the U.S. market at the expense of the purer Class I nickel.

The present weakness in World demand for nickel began in 1975. A slight recovery in nickel sales in 1976 did not last.

Demand failed to measure up to earlier projections, due to much lower rates of growth in World consumption than expected. This resulted in stockpiling of finished metal by mine producers and consumers, and further production cuts at some mines, including some of the new ones.

"OUTLOOK" FOR THE FUTURE

THE MOST IMPORTANT QUESTION THAT CAN BE ASKED ABOUT NICKEL IS "HOW MUCH IS THE WORLD GOING TO **CONSUME** IN THE FUTURE?"

FORECAST TO 1990 — WORLD CONSUMPTION OF PRIMARY NICKEL

(including central planning countries)

a) In 1976, INCO modified its former forecast of 6 per cent per annum average growth in demand to about 4.5 per cent annual average, predicting

1) U.S. growth in demand	2.5 per cent per annum average
2) Europe-growth in demand	4.7 per cent per annum average
3) Japan-growth in demand	6.0 to 6.5 per cent per annum average

Main Source: Sumitomo

The U.S. Dow Jones Service has pointed out that, for some years now, INCO has been somewhat silent on precise forecasts of production, sales and profits and that in July, 1977, it also announced that even its selling prices for nickel products would be confidential.

However, in its prospectus of November, 1977, taking the long-term growth rate of 6% from 1946, INCO guesses that 1980 Western World consumption will amount to 712,000 metric tons. There is an indication, however, that there could be a softening in this figure for a long-term growth rate of nickel consumption during the next 10 years, but the company does not suggest what this new rate would be.

The Chairman of INCO Ltd., Mr. E. Carter, is reported to have said in October, 1977: "The outlook is not bright. INCO's forecasting of such matters has not been too accurate in the past year or so." A Senior Vice President of INCO said that their economists had failed to see the continuing glut in world nickel supplies. "Our expectations of demand levels, of our share of world consumption — ALL THESE FORECASTS WENT WRONG."

b) The Japanese Council on Nickel Problems, an advisory body for the Basic Industries Bureau of the Japanese Ministry of International Trade predicted, in August, 1977, that the rate of growth in Western World consumption of nickel will only average between 4.5 and 5 per cent per year through 1987 and that Western World consumption will rise from 530,000 tons in 1976 to between 600,000 and 700,000 metric tons in 1980 and to between 750,000 and 850,000 tons in 1985.

The Japanese report says that nickel supply "capacity" will rise from the present 700,000 tons to 750,000 tons in 1980 and maybe 900,000 tons in 1985, presumably including sea-bed nickel supplies, i.e. supply capacity will continue to exceed demand in these periods.

J.C.N.P.'s Conclusion: The current nickel oversupply situation will probably continue at least until 1981 and possibly beyond.

c) Amax Inc., U.S.A. projects that 1978 Western World nickel consumption will return to the record level of 1974. Metallgesellschaft calculate this as 554,000 metric tons, which, with the Eastern Bloc, would mean 747,000 tons for the whole world. Amax puts 1977 consumption in the Western World at 3 per cent above 1976. The Economist Intelligence Unit said in December, 1977 that 1977 could well fall by 10 per cent, compared to 1976.

d) The Corrick Study (U.S. Bureau of Mines) indicates an average annual *domestic* consumption *growth rate of only 2.6 per cent* through 1985.

e) The United States Delegation to the U.N. Law of the Sea Conference — on the question of sea-bed nickel — asserted in 1976 that the 25 year historical rate of 6 per cent average growth in world demand will continue.

Please note the U.S. B.O.M. forecast of *average* annual growth in *domestic* consumption of nickel of only 2.6 per cent for the ten years through 1985. An *average* annual growth rate must embrace the effect of years of serious falls in consumption, such as 1971 and 1975. Nickel consumption has not been a steady climb, but is tied to the cyclical pattern of world crude steel production and the durable goods index and this association will presumably remain. 90 per cent of the variation in nickel consumption is attributable to stainless steel and this pattern should continue.

WORSE IS YET TO COME. *Sea-bed nickel production* coming onto world markets in mid-or late 1980's will impact adversely on land-based production, including Ontario's, unless the growth in world consumption of nickel greatly improves, i.e. well beyond an average 4.5 per cent a year rate.

The above forecasts, which range from 6 per cent to 2.5 per cent for various areas, suggest that over the next decade the average overall growth in nickel consumption is unlikely to be more than 3 to 4 per cent per annum.

The alternative approach developed in the following section by Dr. G. Anders indicates that even the 3 to 4 per cent figure may be on the high side through the balance of the century.

LONG-TERM TRENDS IN NICKEL CONSUMPTION

The present stocks of unsold nickel, cut-backs in production and slow-downs or terminations in new mineral project developments are clear proof that past forecasts by industry, by government agencies and by various research bodies were incorrect. Since the very point of forecasting exercises is to prevent the kinds of difficulties now being experienced and since the forecasts upon which actions during the past decade or so were based have little in common except the fact that they turned out to be wrong, it may be suggested that the errors made were not due to minor inaccuracies in the data used or in the calculations carried out, but to some basic error in the common approach to forecasting adopted.

Tables 2.2.2.1 and 2.2.2.2 give some basic data on world nickel production and consumption broken down regionally; Tables 2.2.2.3 and 2.2.2.4 give raw steel production series. Table 2.2.2.5 gives the results of some simple regression analyses carried out on those data and projections for the years 1980 and 2000. Log-linear regression was carried out for the longer time periods where visual inspection of the data points suggested that this would be appropriate. Linear regressions were carried out for the other series as well as for sub-periods of the longer series. The following five charts show data and regression lines graphically.

By comparing the results of several forecast projections made available to us it becomes apparent that the authorities cited clearly extrapolated fairly long (1900 to 1976 or 1947 to 1976) time series on an exponential or log-linear basis. But extrapolations of that kind are not only frequently wrong, or only correct by accident, but are also quite illogical. By the logic of such projection, the ultimate nickel crisis would occur in the latter part of the 28th century — using total world data, or a few hundred years earlier if western world data are used — when nickel consumption would begin to exceed the total weight of the earth.

The question is clearly not "if" but only "when" any exponential growth trend flattens out drastically and that is the point at which the corporate or governmental planner who relied on exponential growth rate extrapolation gets caught with excess stock and excess capacity and possibly the bank which financed such excess stocks and excess expansion too.

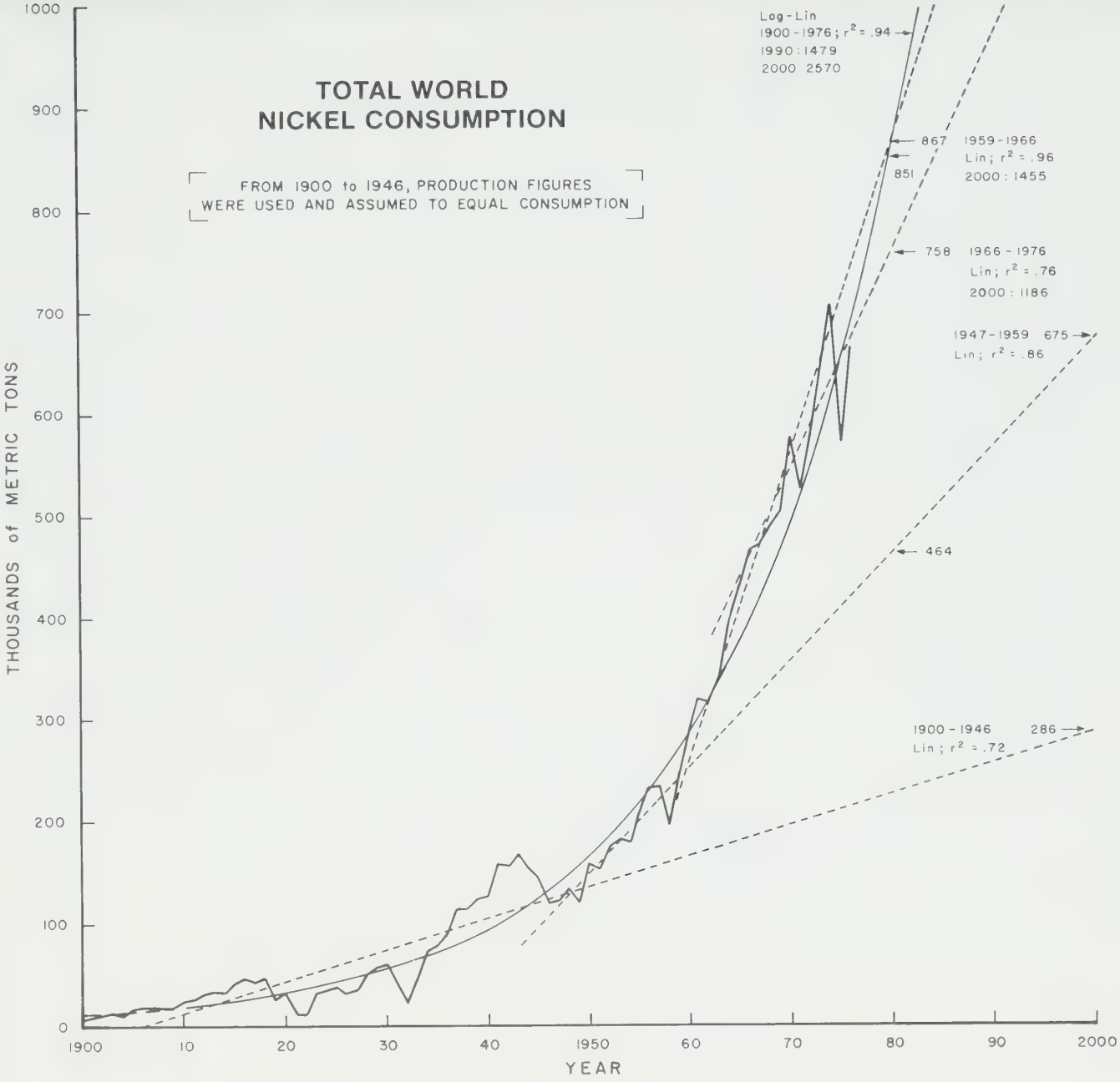
What then are the alternatives to reliance upon exponential growth projections? Steep increases in rates of consumption need not be viewed as evidence of exponential growth rates but as shifts to higher plateaus of consumption or parallel upward shifts of linear growth rates in particular regions, i.e. from patterns of immature or underdeveloped to patterns of mature consumption.

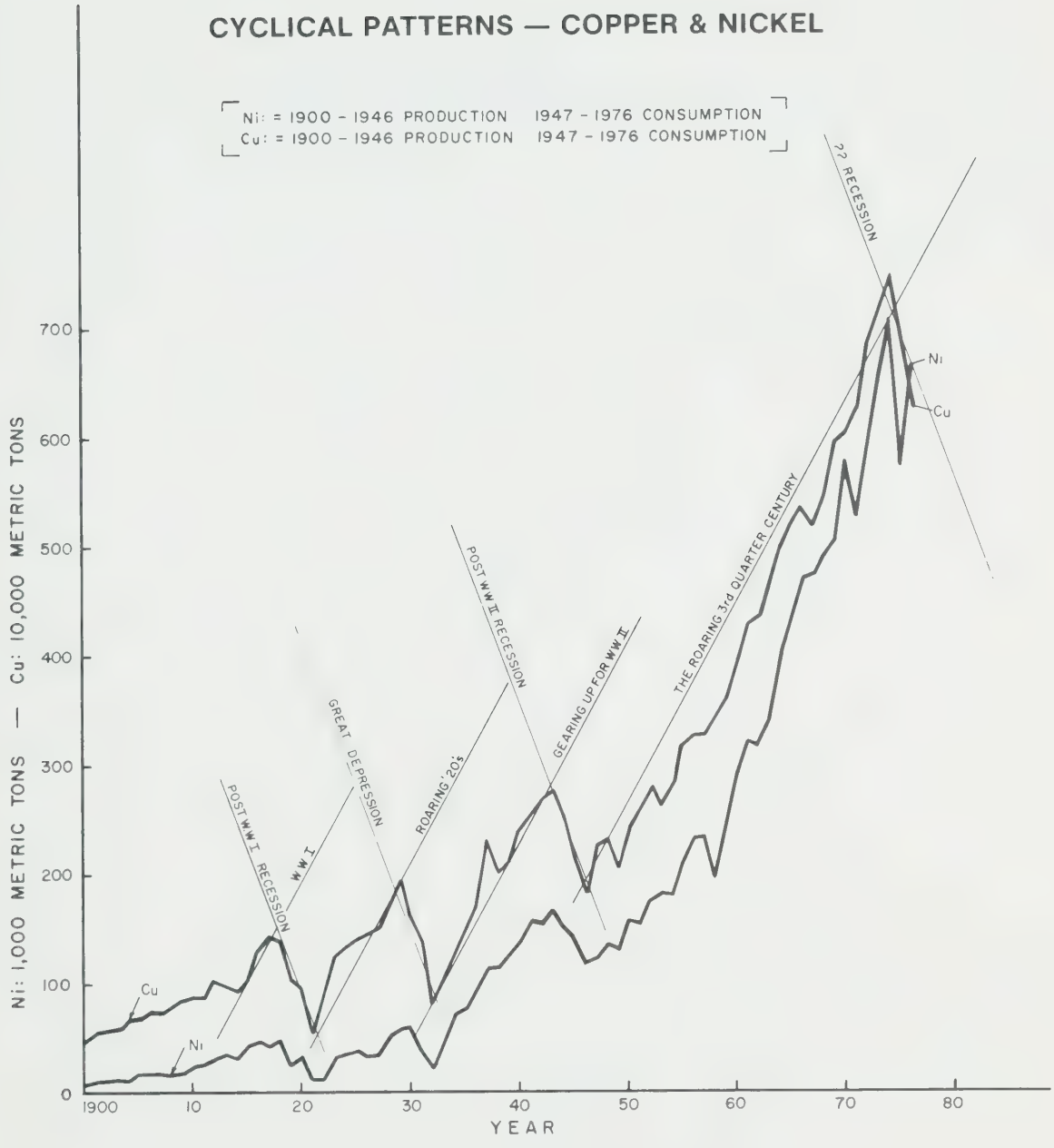
This would simply imply that in Western or market-oriented economies there may be an eventual flattening of growth rates to approach post-World War II rates in the U.S.A., which in turn are not much different fom long-run total world pre-World War II growth rates. In fact, the very steep "late fifties"-"late sixties" rates do show the beginning of a flattening, albeit with wider fluctuations. Broadly speaking, the high rates of growth from the "fifties" through the "sixties" might be attributed to three major factors:

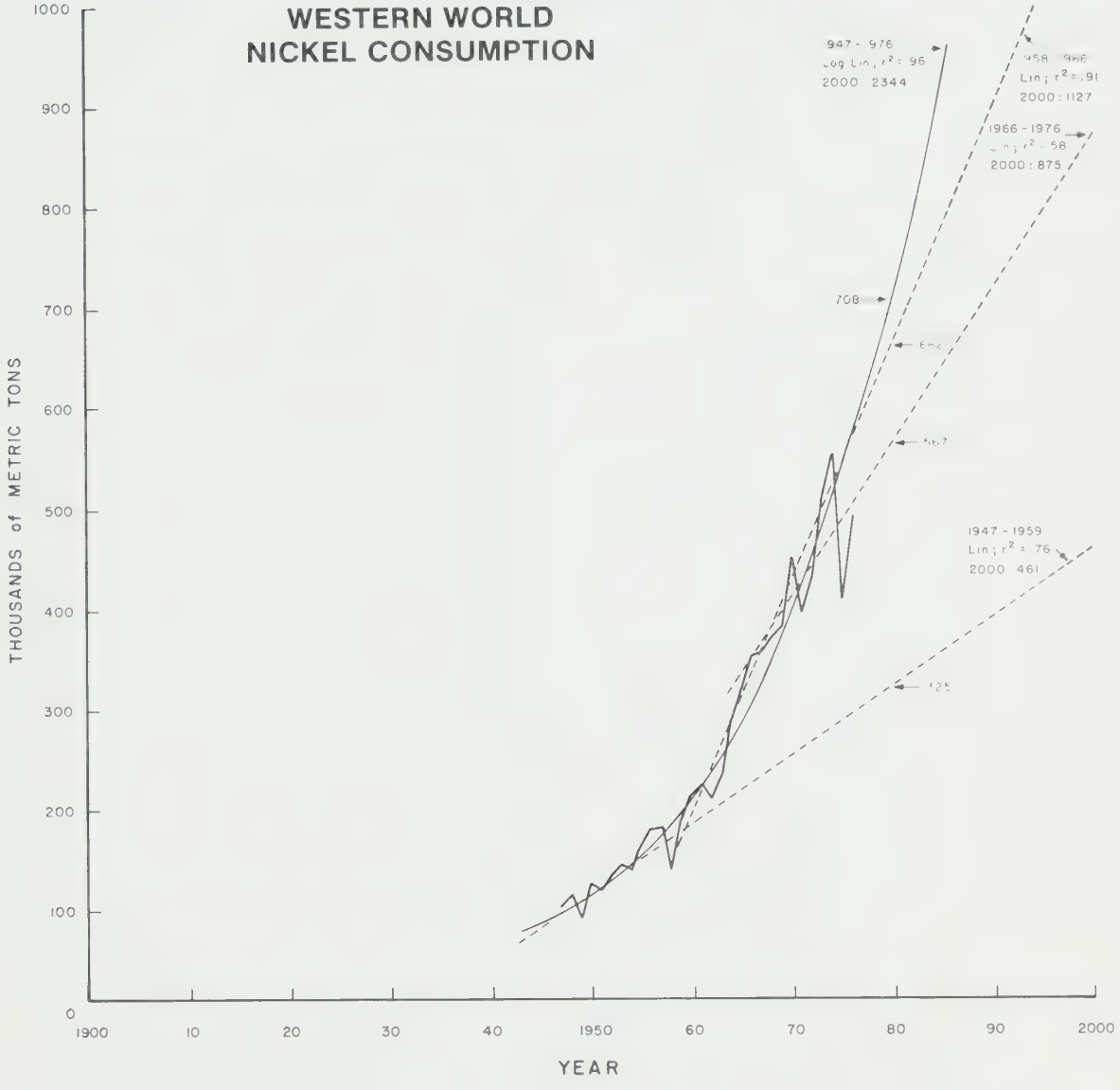
— A catching-up by Western nations to U.S.A. per capita consumption or living standards;

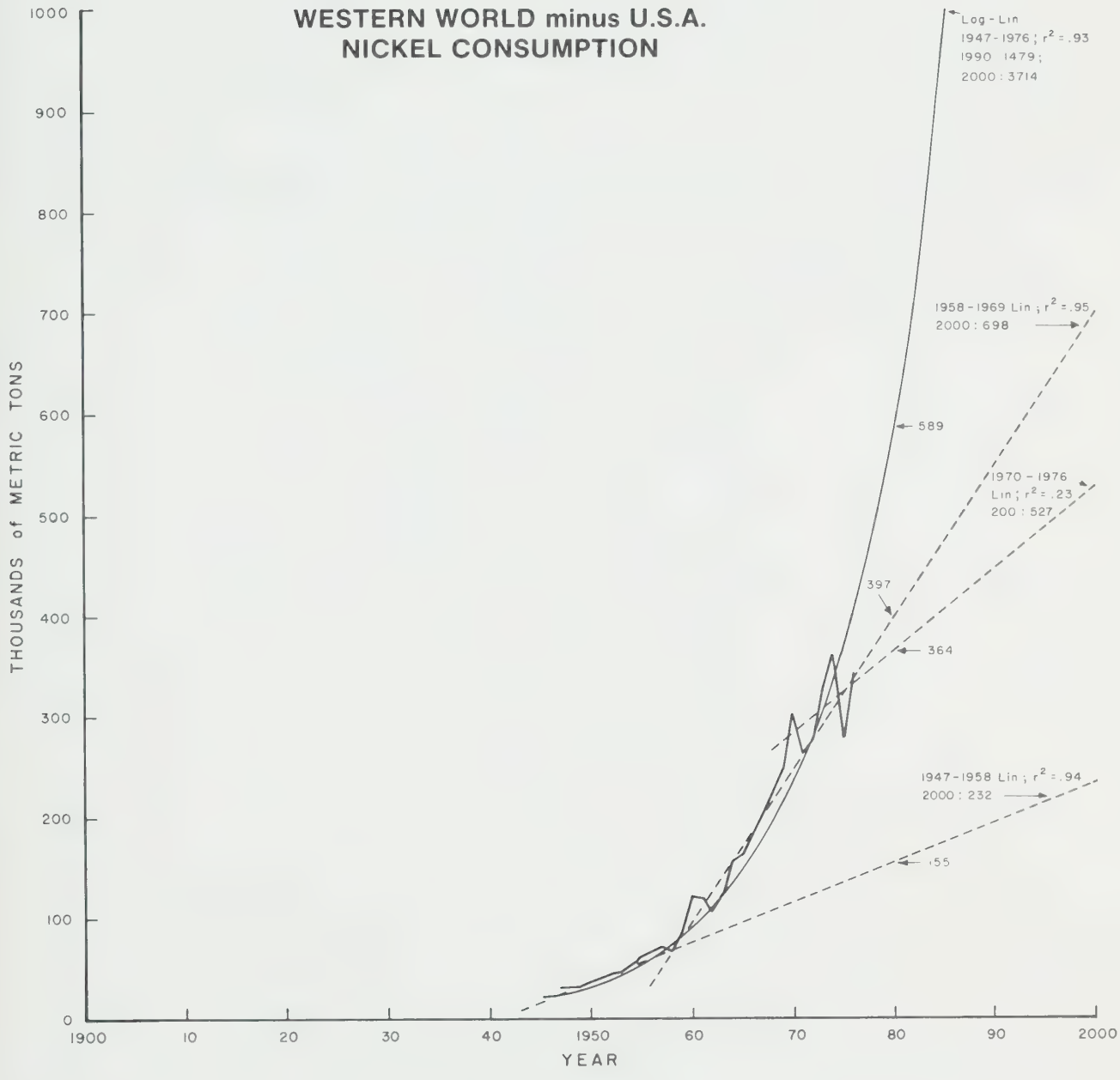
— Inflationary over-expansion of capital goods industries throughout the non-communist world;

— High rates of military consumption through the sequence World War II, Korea, Cold War, Vietnam.

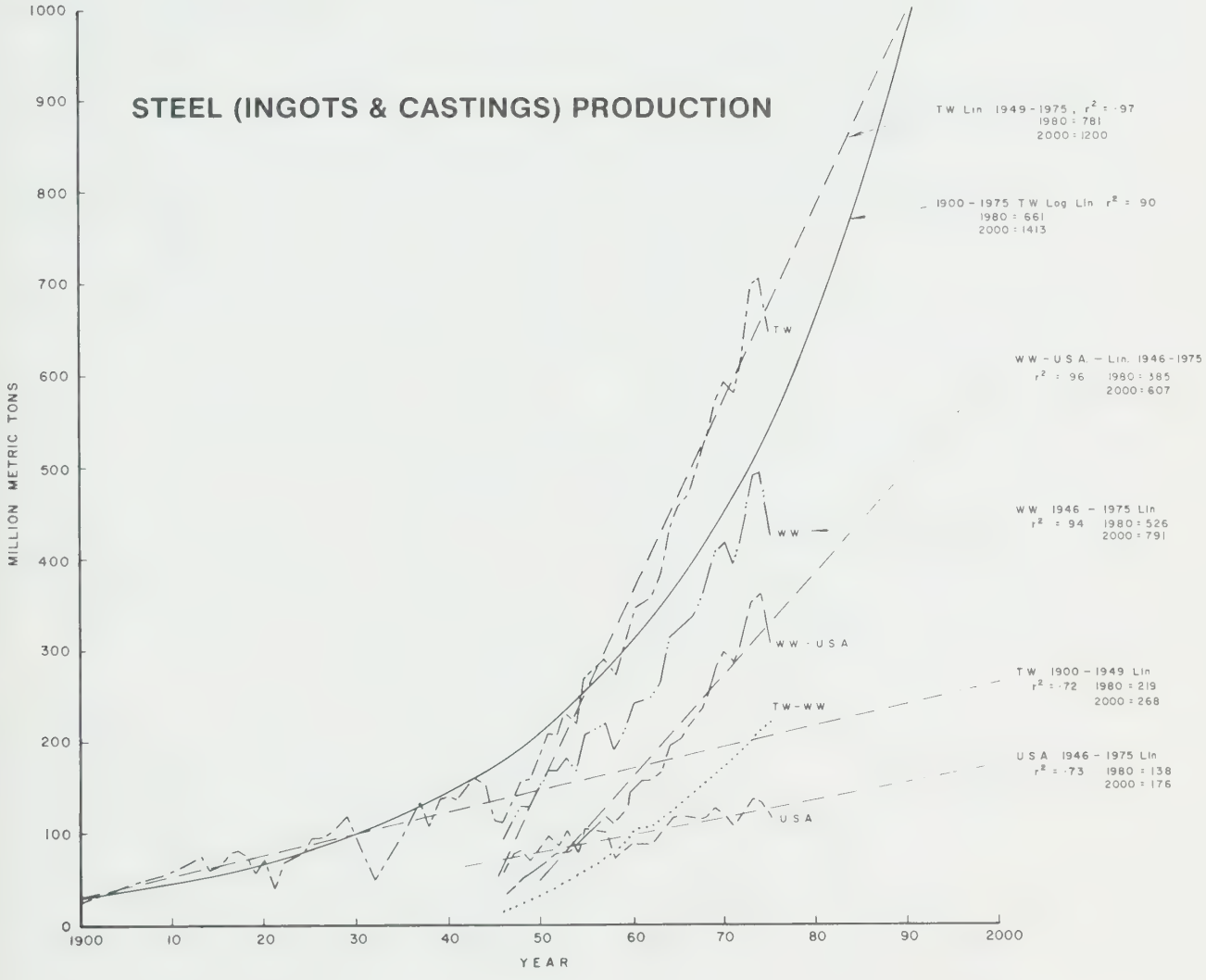

TOTAL WORLD
NICKEL CONSUMPTION
FROM 1900 to 1946, PRODUCTION FIGURES
WERE USED AND ASSUMED TO EQUAL CONSUMPTION
Log-Lin
1900-1976; r² = .94
1990 : 1479
2000 2570
867 1959-1966
Lin; r² = .96
851
2000 : 1455
758 1966-1976
Lin; r² = .76
2000 : 1186
1947-1959 675
Lin; r² = .86
464
1900-1946 286
Lin; r² = .72
THOUSANDS of METRIC TONS
YEAR
0
100
200
300
400
500
600
700
800
900
1000
1900
10
20
30
40
1950
60
70
80
90
2000


CYCLICAL PATTERNS — COPPER & NICKEL
Ni: = 1900 - 1946 PRODUCTION 1947 - 1976 CONSUMPTION
Cu: = 1900 - 1946 PRODUCTION 1947 - 1976 CONSUMPTION
Ni: 1,000 METRIC TONS — Cu: 10,000 METRIC TONS
0
100
200
300
400
500
600
700
1900
10
20
30
40
50
60
70
80
YEAR
Cu
Ni
POST WW I RECESSION
W W I
GREAT DEPRESSION
ROARING '20's
POST WW II RECESSION
GEARING UP FOR W W II
THE ROARING 3rd QUARTER CENTURY
?? RECESSION
Ni
Cu


WESTERN WORLD
NICKEL CONSUMPTION
THOUSANDS of METRIC TONS
YEAR
1000
900
800
700
600
500
400
300
200
100
0
1900
10
20
30
40
1950
60
70
80
90
2000
1947 - 1976
Log Lin; r² = .96
2000 2344
1966 - 1976
Lin; r² = .91
2000 : 1127
1966 - 1976
2000 : 875
1947 - 1959
Lin; r² = .76
2000 461


WESTERN WORLD minus U.S.A.
NICKEL CONSUMPTION
Log - Lin
1947 - 1976 ; r² = .93
1990 1479 ;
2000 : 3714
1958 - 1969 Lin ; r² = .95
2000 : 698
589
1970 - 1976
Lin ; r² = .23
200 : 527
397
364
1947 - 1958 Lin ; r² = .94
2000 : 232
155
THOUSANDS of METRIC TONS
YEAR
0
100
200
300
400
500
600
700
800
900
1000
1900
10
20
30
40
1950
60
70
80
90
2000


NICKEL CONSUMPTION
U. S. A.
1947 - 1976 Lin
r² = .75
1980 = 183
2000 = 251
TOTAL WORLD MINUS WESTERN WORLD
1947 - 1976 Lin
r² = .97
1980 = 186
2000 = 293
1000 METRIC TONS
YEAR
500
400
300
200
100
0
1900
10
20
30
40
50
60
70
80
90
2000


STEEL (INGOTS & CASTINGS) PRODUCTION
MILLION METRIC TONS
YEAR
1000
900
800
700
600
500
400
300
200
100
0
1900
10
20
30
40
50
60
70
80
90
2000
TW
WW
WW - USA
TW-WW
USA
TW Lin 1949-1975, r² = .97
1980 = 781
2000 = 1200
1900-1975 TW Log Lin r² = 90
1980 = 661
2000 = 1413
WW - U.S.A. - Lin. 1946-1975
r² = 96 1980 = 385
2000 = 607
WW 1946 - 1975 Lin
r² = 94 1980 = 526
2000 = 791
TW 1900 - 1949 Lin
r² = .72 1980 = 219
2000 = 268
USA 1946 - 1975 Lin
r² = .73 1980 = 138
2000 = 176

Consumption in the U.S.A. clearly did not account for the explosion in total World or Western World consumption.

The first and second one may be closely related and judgement on the inflationary argument, though convincing on general theoretical grounds, must await more detailed empirical back-up. However, some supplementary considerations based on per capita nickel consumption in various parts of the world may be relevant:

Using 1974 data, the following pattern emerges:

	kg/thousand
U.S.A.	630-920
Western World (industrialized)	305
Western World minus U.S.	220
Total World	180
Total World minus Western World (Eastern Block and 3rd World)	75

Population projections were derived from 1976 Statistical Abstract of the U.S.A., but the breakdown between nation classification used is different from that in the source and is necessarily inconsistent between 1974 and 2000.

The total anticipated weighted increase in world population by the year 2000 is 60%. The population of the more developed countries is expected to increase by 20%. Less developed countries should increase by +70%. As this is roughly in line with post-World War II rates, it may be argued that the effects of population expansion are accounted for in past overall nickel consumption growth rates.

	Consumption in year 2000 in thousand metric tons
U.S.A.	251
Western World minus U.S.	527
Western World	778 — 875
Total World minus Western World	293
Total World	1,037 — 1,131 — 1,180

(the ranges result from differences between sums of individual and aggregate projections)

To the extent that we assume inflationary over-expansion to have played a role — which would result in a further flattening of past — "late sixties" to "early seventies" — trends, these figures would, of course, be upper limits. We may now apply as a check expected rates of per capita consumption to expected rates of population growth. We do not expect significant increases in U.S.A. per capita consumption and apply the upper end of the wide annual U.S.A. per capita consumption range to an expected U.S.A. population in 2000 of 250 million, which would be 230 thousand metric tons. Let us accept the previous, higher figure of 251.

Assume that the more developed nations — essentially those with market economies — will have a population (excluding the U.S.A.) of 925 million in 2000 and will achieve U.S. rates of per capita consumption. Thus total consumption in 2000 will be between 583 and 851 — which is higher than the trend extrapolation of 527. Assume the higher figure and expected Western World consumption in 2000 will be around 851 thousand metric tons.

If it is considered unlikely that the non-developed World, including the communist nations, can achieve more than half the current rate of the Western World minus U.S.A. rate of per capita consumption, this would give a year 2000 total consumption of 560 thousand metric tons — significantly more than indicated by extrapolation (293). Splitting the difference would give 427. Expected consumption (total world) in the year 2000, combining extrapolations and per capita calculations will most likely be between 1,040 and 1,180 thousand metric tons under reasonably optimistic assumptions, i.e. no compensation for inflationary overexpansion during the past two decades, no disastrous changes in technology and reasonable credit availability. Figures between 1,370 and 1,670 constitute the most likely range for great "optimists". Even these latter figures are significantly lower than those provided in recent years in respected forecasts, both published and unpublished. The most likely figure may well be in the 1,100 to 1,200 range.

Lastly, a few words might be said about cycles. Table 2.2.2.2 shows nickel and copper consumption and production data plotted together, as copper shows the same major cyclical movements as nickel, only far clearer. It is interesting that in the pre-World War II period the major ups and downs show a remarkable parallelism, on the one hand in the World War I — roaring twenties — preparation to World War II "ups" and on the other in the 1918-1921, 1928-1932, and post World War II slumps. The boom beginning in the late 1940's again moves in parallel with the earlier upswings.

If the behaviour of copper is any indicator at all to world-wide cyclical phenomena and thus to the likely behaviour of nickel, the suggestion again presents itself that boom/bust cycles only constitute variations from underlying recent trends — the "busts" constituting recoveries from the inflationary over-expansions of the booms — and that any expectations for growth rates in the nickel industry for the next quarter century comparable to those of the past 25 years, must lie in an interpretation of past trends that rests heavily on the Western World catch-up argument and extends it to the rest of the world. To the extent that the nickel industry, since World War II, has come to resemble the copper industry structurally much more than it used to, it may be that cyclical movements in the nickel industry will tend to become as pronounced as those of the copper industry prior to World War II and that patterns of nickel will become as sharply pronounced and more closely resemble the patterns of copper.

TABLE 2.2.2.1

CONSUMPTION OF NICKEL
000 METRIC TONS CONTAINED NICKEL

Year	Total World	Western World	Total World-Western World	U.S.A.	Western World-U.S.A.
1976	665.7	492.2	173.5	150.0	342.2
1975	574.5	409.0	165.5	132.0	277.0
1974	707.2	553.9	153.3	194.5	359.4
1973	655.2	511.5	143.7	182.1	329.4
1972	580.1	434.8	145.3	156.9	277.9
1971	526.6	396.6	130	133.2	263.4
1970	576.6	451.6	125	149.1	302.5
1969	502.8	382.8	120	136.6	246.2
1968	490.4	370.4	120	144.5	225.9
1967	473.0	358.0	115	157.7	200.3
1966	467.6	352.6	115	170.4	182.2
1965	431.0	321.0	110	156.1	164.9
1964	401.7	291.7	110	133.3	158.4
1963	342.9	234.9	108	112.9	122.0
1962	318.0	213.0	105.0	107.7	105.3
1961	320.8	225.8	95.0	107.5	118.3
1960	292.7	218.7	74.0	98.1	120.6
1959	249.2	190.2	59.0	102.2	87.5
1958	196.4	140.4	56.0	71.7	68.7
1957	235.3	183.7	52.0	111.1	72.6
1956	230.9	182.4	49.0	115.7	66.7
1955	206.9	161.8	45.0	99.9	61.9
1954	181.2	138.2	43.0	85.9	52.3
1953	182.3	141.3	41.0	95.9	45.4
1952	175.1	137.1	38.0	92.0	45.1
1951	154.4	120.4	34.0	78.6	41.8
1950	157.1	127.1	30.0	90.7	36.4
1949	119.5	94.0	25.5	62.0	32.0
1948	134.9	116.4	18.5	84.9	31.5
1947	122.1	105.1	17.0	73.3	31.8

Source: Metallgesellschaft

TABLE 2.2.2.2

TOTAL WORLD MINE PRODUCTION CONTAINED NICKEL 1900 - 1946: 000 METRIC TONS

Year		Year		Year		Year		Year	
1900	8	1910	24	1920	33	1930	60	1940	138
1901	10	1911	26	1921	12	1931	40	1941	159
1902	11	1912	32	1922	12	1932	22	1942	158
1903	12	1913	34	1923	31	1933	46	1943	168
1904	11	1914	32	1924	35	1934	72	1944	154
1905	16	1915	42	1925	37	1935	77	1945	144
1906	18	1916	46	1926	34	1936	90	1946	118
1907	18	1917	44	1927	36	1937	115		
1908	17	1918	47	1928	51	1938	115		
1909	18	1919	26	1929	58	1939	125		

Source: Metallgesellschaft.

TABLE 2.2.2.3

RAW STEEL PRODUCTION
(Ingots and Castings)

(In million metric tons)

Year	Total World	Western World	Total World-Western World	U.S.A.	Western World-U.S.A.
1975	646.0	423.9	222.1	116.6	307.3
1974	710.1	494.9	215.2	132.0	362.9
1973	697.2	491.0	206.2	136.6	354.4
1972	630.0	434.3	195.7	120.8	313.5
1971	580.5	394.6	185.9	109.0	285.6
1970	593.5	418.4	175.1	119.2	299.2
1969	573.4	408.2	165.2	128.0	280.2
1968	528.5	371.0	157.5	119.1	251.9
1967	496.8	346.6	150.2	115.2	231.4
1966	470.9	331.7	139.2	118.7	213.0
1965	456.4	324.0	132.4	119.1	204.9
1964	434.6	311.3	123.3	115.1	196.2
1963	383.1	268.6	114.5	99.0	169.6
1962	357.5	248.2	109.3	89.0	159.2
1961	353.9	247.6	106.3	88.8	158.8
1960	346.2	241.1	105.1	89.9	151.2
1959	304.6	213.0	91.6	84.6	128.4
1958	271.2	191.2	80.0	77.2	114.0
1957	292.1	220.2	71.9	102.0	118.2
1956	282.3	215.2	67.1	104.3	110.9
1955	269.9	207.6	62.3	106.0	101.6
1954	223.4	167.1	56.3	80.0	87.1
1953	234.0	182.1	51.9	101.0	81.1
1952	211.0	164.3	46.7	84.2	80.1
1951	210.3	168.8	41.5	95.1	73.7
1950	188.6	153.1	35.5	87.6	65.5
1949	160.0	129.4	30.6	70.5	58.9
1948	155.5	130.7	24.8	80.2	50.5
1947	136.2	116.6	19.6	76.7	39.9
1946	111.6	94.4	17.2	60.2	34.2

Source: American Iron and Steel Institute.

TABLE 2.2.2.4

TOTAL WORLD PRODUCTION OF STEEL INGOTS AND CASTINGS

1900 - 1945

(in million metric tons)

Year		Year		Year		Year		Year	
1945	115	1939	136	1929	121	1919	59	1909	
1944	154	1938	109	1928	110	1918	77	1908	
1943	162	1937	135	1927	102	1917	83	1907	
1942	153	1936	124	1926	93	1916	78	1906	
1941	138	1935	99	1925	91	1915	66	1905	45
1940	141	1934	82	1924	79	1914	61	1904	
		1933	68	1923	78	1913	76	1903	
		1932	51	1922	69	1912	73	1902	
		1931	70	1921	44	1911		1901	
		1930	94	1920	73	1910	61	1900	28

Source: American Iron and Steel Institute.

TABLE 2.2.2.5

COMMODITY PROJECTIONS

Commodity	Region	Period	Regression	r^2	S	1980	2000	Remarks
Nickel	Total World	1900-1976	Log-Linear	.94	.02	851	2570	to 1946 Production from 1947 Consumption
	Total World	1947-1976	Log-Linear	.97	.03	977	3467	Consumption
	Total World	1947-1949	Linear	.86	10.51	464	675	Consumption
	Total World	1959-1966	Linear	.96	29.42	867	1455	Consumption
	Total World	1966-1976	Linear	.74	21.41	758	1186	Consumption
	Total World	1900-1946	Linear	.72	2.98	226	285	Production
	Western World	1947-1976	Log-Linear	.96	.03	708	2344	Consumption
	Western World	1947-1959	Linear	.76	6.81	325	461	Consumption
	Western World	1958-1966	Linear	.91	23.27	662	1127	Consumption
	Western World	1966-1976	Linear	.58	15.39	567	875	Consumption
	Total World-West. World	1947-1976	Linear	.97	5.36	186	293	Consumption
	U.S.A.	1947-1976	Linear	.75	3.41	183	251	Consumption
	Western World-U.S.A.	1947-1976	Log-Linear	.93	.04	589	3714	Consumption
	Western World-U.S.A.	1947-1958	Linear	.94	3.88	155	232	Consumption
	Western World-U.S.A.	1958-1969	Linear	.95	14.96	397	698	Consumption
	Western World-U.S.A.	1970-1976	Linear	.23	8.14	364	527	Consumption
Raw Steel (Ingots and Castings)	Total World	1900-1975	Log-Linear	.90	.02	661	1413	Production
	Total World	1900-1949	Linear	.72	2.40	219	268	Production
	Total World	1949-1975	Linear	.97	20.93	781	1200	Production
	Western World	1946-1975	Linear	.94	13.26	526	791	Production
	U.S.A.	1946-1975	Linear	.73	1.90	138	176	Production
	Western World-U.S.A.	1946-1975	Linear	.96	11.09	385	607	Production

Source: Data in Tables 2.2.2.1 — 2.2.2.4

2.2.3 CONSUMPTION BY INTERMEDIATE PRODUCT

On a regular basis the only data which is available describing Western World intermediate nickel product consumption is obtained from INCO Ltd. annual reports over the period 1960-1971. Prior to this time and after 1971, this information is not available. Table following gives this data broken down by nickel consumed in metric tons in stainless steel, high nickel alloys, nickel plating, construction alloys, iron and steel castings, copper and brass products, and other categories.

The source quoted has adjusted the INCO Ltd. data to conform with consumption listed in Metallgesellschaft and the World Bureau of Metal Statistics. However, it is the percentage breakdown that is important, and trends in the individual categories can assist in predicting what the future holds for the nickel industry.

For instance, over this eleven-year period to 1971, consumption of nickel in stainless steel grew from 34% of total consumption to 41%. Evidence is available to support the assumption that this trend has persisted through to 1976, and therefore the nickel industry remains very dependent upon stainless steel in particular, and the steel industry in general. The outlook for the Western World steel industry is of course as depressed as that of the nickel industry.

Consumption in high nickel alloys growth over this period remained relatively constant at approximately 14%. These alloys are of course used extensively in the aerospace industry which is currently at a cyclical high in profitability and output levels.

Nickel plating has also remained fairly constant in the 14-16% range. This use is primarily consumer products, e.g. kettles, flatware, etc., plus automotive trim and bumpers.

Nickel consumption in constructional alloy steel declined slightly over the 11 year period, and likely reflects substitution by other metals in high strength low alloy steel such as molybdenum and columbium. Nickel in iron and steel castings has also been on the decline, decreasing from 11% of total consumption in 1960 down to 8% in 1969. There is no apparent trend in the consumption of nickel and copper in brass products. However, it would be difficult to discern any trends from this end-use since they are a relatively minor part of the market.

The outlook for the industries upon which these intermediate nickel products depend is discussed in detail in the following section.

INTERMEDIATE NICKEL PRODUCT CONSUMPTION
(Non-communist)

Industry	Stainless Steel		High-Nickel Alloys		Nickel Plating		Construction Alloys		Iron & Steel Castings		Copper & Brass Products		Other	
Metric Year	'000 Tons	%	'000 Tons	%	'000 Tons	%	'000 Tons	%	'000 Tons	%	'000 Tons	%	'000 Tons	%
1972-1977	Not available after 1971 on Western World basis.													
1971	153	41	45	12	60	16	37	10	34	9	11	3	35	9
1970	180	41	60	14	58	13	46	11	39	9	14	3	41	9
1969	146	41	51	14	47	13	43	12	30	8	12	3	31	9
1968	137	37	55	15	53	14	40	11	37	10	11	3	37	10
1967	133	37	50	14	54	15	38	11	38	11	13	3	32	9
1966	122	35	51	14	55	16	41	12	36	10	15	4	33	9
1965	106	33	44	14	50	16	40	13	33	10	14	4	31	10
1964	101	35	36	12	48	17	38	13	30	10	11	4	26	9
1963	72	31	33	14	40	17	31	13	26	11	10	4	23	10
1962	58	27	33	15	37	17	27	13	27	13	10	5	21	10
1961	74	33	34	15	34	15	30	13	25	11	9	4	20	9
1960	75	34	30	14	33	15	28	13	24	11	9	4	20	9

Source: Dept. of Energy, Mines and Resources Canada, MR 157, Ref. Inco Ltd. (annual reports), adjusted to conform with consumption listed in Metallgesellschaft A.G. in period 1960-64 and World Bureau of Metal Statistics thereafter.

2.2.4 CONSUMPTION BY END-USE INDUSTRY

The following table depicts Western World nickel consumption according to its end-use in specific industries:

Consumption by End-Use Industry

	1976
	%
Consumer Products	15
Machinery and Transportation Equipment	14
Automotive	10
Electronic and Electrical Equipment	8
Chemical and Petroleum Industry	18
Process Equipment	8
Aircraft Industry	7
Energy Conversion Equipment	4
Marine Industry Products	3
Architecture	3
Coinage	2
Others	8
	100

Source: Projections by Mineral Resources Branch.
Based on INCO Ltd. data and other industry sources.

The largest single end-use for nickel is in consumer and other fabricated metal products. These range from cutlery to hand tools, general hardware, electrical kettles, etc. Several factors contribute to consumer appeal, the most obvious being the bright finish imparted by the nickel plating but also durability, strength, and corrosion resistance are also important.

The next major important end-use, that of machinery and transportation equipment, is based on nickel consumption in cast iron and in nickel bearing alloy steels. These are widely used in machinery to provide strength and in some cases to impart corrosion resistance.

In the automotive industries, electroplating is by far the largest end-use of nickel. This is primarily in the chromium trim on the bodies of the cars as well as the bumpers. Some tank trucks utilize nickel bearing stainless steel bodies however, and stainless steel is often used in rocker panels, trim, and wheel covers of automobiles. Not only is the medium term outlook for world automobile production rather dismal but also there is a marked tendency to use smaller areas of chromium on standard size automobiles. The popularity of compact models will also lead to scaling down of the amount of nickel consumed per car.

With the energy "panic", the public has become more and more resistant to purchasing heavy automobiles. Among the numerous weight saving design implementations is the substitution of aluminum and plastic for nickel plated trim. So far these substitutes have only been used on compact and relatively low production models, and therefore, the impact has not yet been felt in the industry. In 1978 the Chevrolet and Pontiac divisions of General Motors plan to expand their use of soft plastic front and rear bumpers.

Electronic and electrical industry end-uses of nickel (including machinery) consists mainly of resistance alloys which contain up to 80% nickel. High magnetic permeability nickel alloys followed by nickel bearing glass to metals metal seals and transistors account for the remainder.

In the chemical, petroleum, and other process industries, manufacturers use nickel in the form of alloys applied to equipment parts which are exposed to corrosive chemicals. Stainless alloys and heat resisting steels containing more than 8% nickel are used very commonly along with wrought and cast nickel alloys which contain up to 99% nickel for very strong caustic solutions. One bright spot in this area is the potential use of desalination equipment which requires extensive quantities of copper-nickel alloys to withstand the highly corrosive process of distilling sea water. However, such projects have been on the horizon for many years and they have yet to come to the detailed feasibility and financing stage. Therefore, this particular end-use is very unlikely to have a major impact on medium term nickel markets.

In the aircraft and aircraft parts industries, super alloys are the major nickel bearing intermediate products which are used. Such super alloys have been designed to have very extraordinary performance characteristics such as strength under extremely high temperatures. Applications include gas turbines, turbo super chargers and jet engines. Almost all the super alloys contain substantial quantities of nickel and it is of course a very important fact that cost is no object.

Energy conversion uses include batteries (also tied to the automobile industry), electrical turbines and other products described above.

Marine applications are largely nickel/copper or copper/nickel alloys from which the hulls of boats are fabricated, and are important for other parts of boats which are exposed to salt water. Excluding hulls, the cost of these alloy parts is very minor compared to replacement costs. Hulls of smaller vessels such as shrimp boats can often economically utilize nickel/copper alloy. In architecture, including general building construction, most of the nickel is used in the form of stainless steel curtain wall trim. Additionally, nickel bearing high-strength low alloy steels are used for structural members because of their high strength to weight ratios.

Coinage was once a major end-use for nickel. At present though, the consumption of nickel in this area is diminutive compared to the applications described above. However, some substitution of nickel for silver has occurred following the rapid price increases for this precious metal.

Other and miscellaneous uses would include nickel salts, employed as catalysts, e.g. for the hydrogenation of fats and oils, plus its use in ceramics to form a bond between the enamel paint and iron.

2.2.5 NICKEL CONSUMPTION BY RAW MATERIAL

The principal nickel raw materials which are produced and sold on world markets are electrolytic nickel, nickel oxide, (that is nickel oxide 75, and nickel oxide 90), various grades of ferronickel, high purity nickel briquettes and ultra high purity nickel carbonyl pellets. Other forms would include nickel sulphate and miscellaneous nickel chemicals.

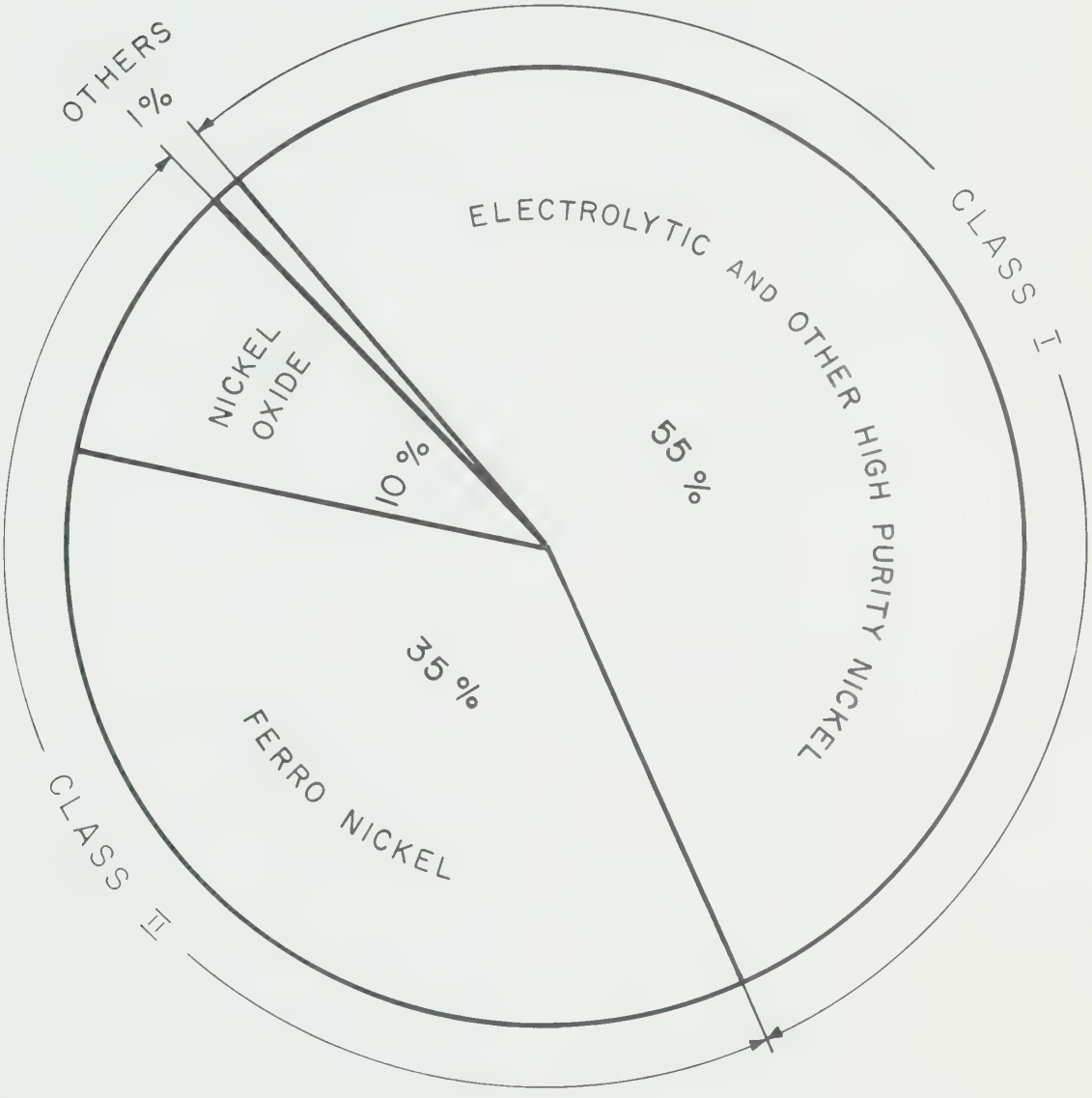
The breakdown of nickel consumption worldwide by such raw materials has not been published to our knowledge on a historical year-by-year basis. However, the following chart attempts to estimate this breakdown for 1976. One can, however, deduce some of the trends from the following table which gives U.S. consumption of raw materials over the past 15 years. One obvious conclusion that can be drawn is the fact that steel companies have been substituting lower cost nickel such

as ferro and oxide for higher priced nickel such as electrolytic, briquettes, etc. This form of substitution has been more commonplace in the U.S. than in many other parts of the world, owing to its higher level of technology. For instance the A.O.D. furnace developed by Union Carbide allows less pure nickel to be used in the production of stainless steel. On the other hand, some countries with a very highly developed technology such as in West Germany are resistant to using lower quality material, even where there is a cost advantage. Inflation does, however, make it more important to use any advantage that ferro and oxide can offer, and, therefore, the trend to using less costly material is likely to become more commonplace and to continue well into the foreseeable future.

Lateritic ores have traditionally been used to produce ferronickel. These ores naturally contain iron oxide which makes its way into the product in reduced form, some iron does have to be added in order to produce an acceptable grade. Generally speaking, this product contains nickel with a balance of iron. From the first sales of this product on world markets until the turn of the year, producers of ferronickel never charged for the iron content, i.e. this has formed a type of discount. Therefore, when computing the laydown cost of second class nickel to a consumer's plant, one would have to take into account the "free" iron since such products are invariably used in steel making. The other important Class II nickel product is nickel oxide, and this does not have the advantage of "free" iron content.

One barrier which existed prohibiting the use of lateritic ores in the production of Class I nickel was their inherently high cost of concentrating and smelting. INCO's carbonyl process, however, can use mattes from either laterites or sulphides without any acknowledged problems. Therefore, that company is not locked into Canada even for the production of high purity products. Similarly Sherritt Gordon's ammonia pressure leach process also removes this barrier.

1976
WORLD NICKEL CONSUMPTION
BY
PRIMARY RAW MATERIAL*



* Estimated by the Mineral Resources Branch,
Ontario Ministry of Natural Resources.

(Total 101% Owing to Rounding)

2.2.6 U.S. CONSUMPTION OF NICKEL

The U.S.A. is the world's largest consumer of nickel and Ontario's most important nickel market. Without question, the historical consumption patterns in the U.S. have established trends in the rest of the Western World. While technological changes introduced in other parts of the world have disrupted the dominance of U.S. consumers, as of 1975 the U.S. market still accounted for about 32 per cent of all Western countries. Separate tables depict historical consumption of primary nickel, the breakdown in consumption by end use and raw material sources.

Unfortunately, detailed information on intermediate and end-uses of nickel are not published for most countries. Therefore, U.S. trends must be used as a guide to total Western World, in any fine tuning of demand forecasts.

With respect to intermediate products it might be said that a wider range was in common usage in the U.S. Class II products including both nickel oxide and ferronickel are more acceptable to U.S. consumers than their European counterparts. Hence the U.S. experience suggests strong growth for these materials if further substitution for refined nickel occurs in that part of the world.

Intermediate and end uses of nickel such as superalloys, nickel-copper alloys and permanent magnet alloys also enjoy wider application in the U.S. One table illustrates the growth in the past five years for these categories and also allows the reader to enter which categories have performed the best in the current recession. From the years given, the inescapable conclusion is that specialized nickel uses, cast iron alloys, superalloys and nickel-copper alloys have been the losers during the last five years. In 1976, permanent magnet alloys, electroplating and chemical uses demonstrated the greatest resilience.

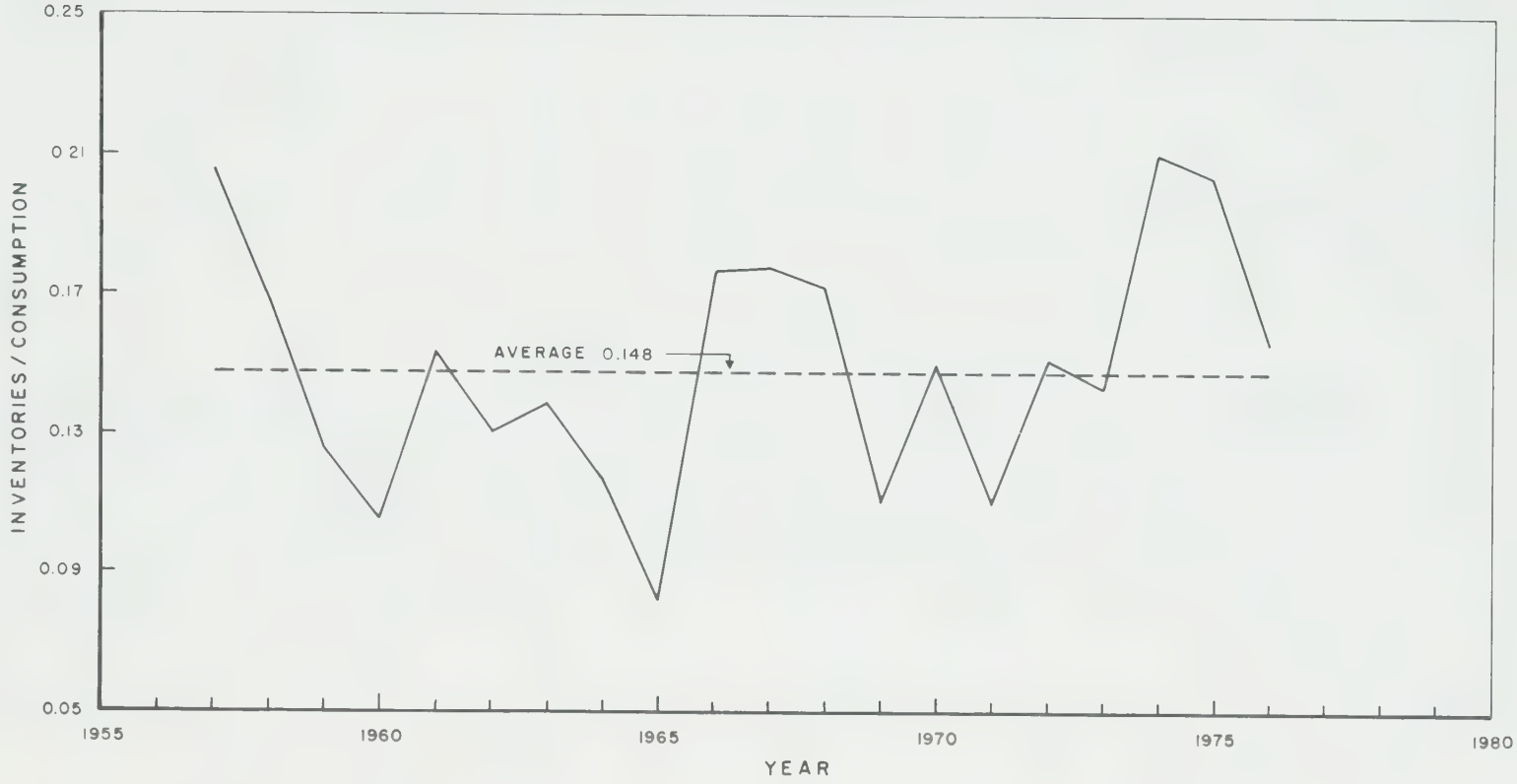
A table in Appendix A5 provides a perspective of consumption patterns by end use industry.

U.S. NICKEL CONSUMPTION GROWTH

In the past twenty years, U.S. nickel consumption has experienced tremendous spurts of growth, as indicated by the statistical data presented. Specifically, the period 1958 to 1966 saw U.S. consumption soaring to 170,401 metric tons which was close to the historical peak reached in 1974. During this 9 year period consumption growth averaged 10.1% per annum. Since then, however, the *trend has flattened* and in the twenty years period ending in 1976 this growth had moderated to 3%.

The implications of any changes in U.S. consumption should be carefully analyzed, considering the importance of this market to Canada and to Ontario. Therefore, it is disturbing to note any trend to lower term growth. Although the nickel industry is well on its way to maturity it could well be erroneous to assume that it is now in the same class as copper, for instance. Nonetheless, for the shorter term one must be prepared to accept the possibility of weak U.S. demand, despite the exciting potential which exists in high performance applications.

U.S. NICKEL CONSUMPTION
VS
CONSUMER STOCKS



2.2.7 WESTERN WORLD NICKEL DISTRIBUTION

MAJOR NICKEL CONSUMERS IN THE WORLD

THESE ARE SOME OF THE MOST IMPORTANT ORGANIZATIONS IN THE WORLD AS FAR AS ONTARIO'S NICKEL PRODUCTION IS CONCERNED.

THEY DECIDE WHAT NICKEL THEY WILL BUY.

ARGENTINA
- Establecimientos Metalurgicos Santa Rosa S.A. Buenos Aires

AUSTRALIA
- Broken Hill Proprietary Ltd., Melbourne
- Commonwealth Steel Co. Ltd. — Waratah, N.S.W.
- Australian Mint, Canberra

AUSTRIA
- Austrian Mint, Vienna
- Gebr. Boehler and Co. AG — Vienna
- Schoeller-Bleckman Stahlwerke AG — Vienna
- V.O.E.S.T., Linz and Liezen
- Alpine Montangesellschaft
- Steierische Gussstahlwerk
- Langbein — Pfanhauser
- Metallwerk Plansee

BELGIUM
- Belgian Mint, Brussels
- Cuivre de Zinc de Liege
- Cockerill — Ougree S.A., Seraing
- Griffin, foundry
- Fabrique Nationale, Herstael
- Soc. Met. Hainaut-Sambre
- Forges de Jemappes
- S.A.F.A.N., Brussels
- S.A.F.A.K., Brussels
- S.A. des Usines Gilson
- Allegheny-Longdoz S.A. — Brussels
- S.A. des Laminoirs Deflandre — Sauheid-Chenee
- S.A. Usines Emile Henricot — Court St. Etienne

BRAZIL
- Acesita-Cia Acos Especiais Itabira — Rio de Janeiro
- Acos Villares S.A. — Sao Paulo, S.P.

CANADA
- Royal Canadian Mint — Winnipeg
- Atlas Steels Co. — Welland, Ontario
- Colt Industries (Canada) Ltd. — Sorel, Quebec
- Sherritt Gordon — Alberta

ENGLAND
- British Steel Corporation, (incorporating United Steels, English Steel, Samuel Osborn, Richard Thomas and Baldwins, Hadfield's)
- Henry Wiggin (INCO)
- Daniel Doncaster (INCO)
- Royal Mint, Llantrisant — Wales
- Mint (Birmingham) Ltd.
- Firth-Vickers Stainless Steels Ltd. — Sheffield
- Firth Brown Steels
- Brown Bayley Steels
- Jonas and Colver (Novo) Ltd.
- British Driver-Harris — Cheadle
- Wilmot Breeden
- Harshaw
- Imperial Metals (I.C.I.)
- Yorkshire Copper
- Silvercrown
- David Brown Foundries
- N.C. Ashton
- Barker and Allen
- Viner's, Sheffield

FINLAND
- Outokumpu Oy.

FRANCE
- French Mint
- Forges et Acieries de Bonpertuis — Rives sur Fures
- Creusot-Loire — Paris and Le Creusot
- Fives-Lille-Cail — Lille
- Usines Schneider
- Acieries de Firminy
- Forges de Gueugnon — Paris and Gueugnon
- Ste. Nouvelle des Acieries de Pompey — Neuilly-sur-Seine
- Pechiney-Ugine-Kuhlmann, (Ugine Aciers) — Paris and Ugine, Savoie
- Acieries de Longwy
- Metalimphy
- Chatillon Commentry
- Commentry — Fourchambault
- Pont-a-Mousson Steelworks
- Comptoir Lyon Allemand E. Louyot et Cie. — Paris

WEST GERMANY
- D.E.W., (Deutsche Edelstahlwerke A.G.) — Krefeld
- V.D.M., (Vereinigte Deutsche Metallwerke) — Altena, Westfalen
- V.D.N., (Vereinigte Deutsche Nickelwerke) — Schwerte, Ruhr
- The German Mint
- Friedrich Krupp Huettenwerke A.G. — Bochum, (incorporating Gussstahlwerk Krupp and Krupp Widia Fabrik-Essen)
- Stahl — und Roehrenwerk Reisholz
- Dortmund — Hoerde Union
- Kloeckner Georgsmarienwerke A.G.
- Stahlwerke Suedwestfalen A.G. — Geisweid
- Stahlwerke Bochum A.G.
- Phoenix-Rheinrohr A.G.
- Gebr. Boehler and Co. A.G. — Dusseldorf-Oberkassel
- Edelstahlwerk Witten
- Ruhrstahl A.G. — Witten
- Mannesmann Huettenwerke A.G.
- Edelstahlwerke Buderus A.G. — Wetzlar
- Stahlwerke Roechling — Buderus
- Volkswagenwerk
- Ford Koeln — Cologne
- Osnabrucker Kupfer and Drahtwerk
- Hindrichs Aufferman
- Vacuumschmelze G.m.b.h., Hanau
- Gesellschaft fur Elektrometallurgie, Dusseldorf
- Opel (General Motors)

N.S.U. Neckarsulm
Werner Meis
Bayer — Leverkusen
Langbein — Pfanhauser
Bergische Stahlindustrie
Robert Bosch G.m.b.H.
Wielandwerke — Ulm
Isabellenhuette — Hesse
Sundwiger Messingwerk
R. and G. Schmoele
Erkenzweig and Schwemann
Knorr Bremse
Breitenbach — Weidenau
Achenbach – Buschhutten
Koelsch-Folzer Werke — Siegen
Karl Buch — Weidenau
Schmidt and Clemens — Berghausen
Schmiedag
Stahlschmidt — Dusseldorf-Oberkassel
Pose-Marre — Erkrath
Montforts
Degussa — Hanau
Gontermann – Peipers
Karl Schmidt
Hugo Wachenfeld and Co. — Dusseldorf-Oberkassel
Busch-Jaeger

INDIA

Indian Mint
Hindustan Steel Ltd. — Ranchi
Mahindra Ugine Steel Co. Ltd. — Bombay
Tata Steelworks, Jamshedpur

HUNGARY

Diosgyor Works

ITALY

Breda Siderurgica
F.I.A.T., Turin
Italian Mint
Acciaierie di Bolzano SpA — Bolzano
Cogne, Turin
Ilssa Viola — Milan
Terninoss Acciai Inossidabili SpA — Milan
Lombarde Falck
S.M.I., Societa Metallurgica Italiana, Firenze
Italiana Driver-Harris

JAPAN

Japanese Mint
Aichi Steel Works Ltd. — Tokai-shi, Aichi-ken
Daido Steel Co. Ltd. — Naka-ku, Nagoya
Hitachi Metals Ltd. - Tokyo
Kawasaki Steel Corp. - Fukia-ku, Kobe
Kobe Steel Ltd. — Kobe
Myodo Metal Co. Ltd. – Niigata
Nippon Kinzoku Co. Ltd. — Tokyo
Nippon Metal Industry Co. Ltd. — Tokyo
Nippon Stainless Steel Co. Ltd. — Tokyo
Nippon Steel Corporation — Tokyo
Nippon Yakin Kogyo Co. Ltd. — Tokyo
Nisshin Steel Co. Ltd. — Tokyo
Sanyo Special Steel Co. Ltd. — Himeji City
Sumitomo Metal Industries Ltd. — Higashi-ku, Osaka
Tokushu Seiko Co. Ltd. — Tokyo

LUXEMBOURG

A.R.B.E.D. Steelworks

NETHERLANDS

Netherlands Mint
Philips, Eindhoven
Stork Werkspoor
Gero
Dikkers
Nedona
Demka
Veco

NORWAY

Norwegian Mint

SOUTH AFRICA

The Southern Cross Steel Co. (Pty) Ltd. — Johannesburg
South African Mint

SPAIN

Acerias y Forjas de Azcoitia S.A. —
Carretera de Zumarrage, Azcoitia
Spanish Mint

SWEDEN

Svenska Metallverken
Avesta Jernverks A.B. — Avesta
A.B. Bofors — Bofors
Fagersta A.B. Fagersta
Granges Stal Nyby Bruk – Nyby near Torshalla
Sandvik A.B. — Sandviken
Stora Kopparbergs Bergslags A.B., Specialstalverken –
Falun
Akers Styckebruk
Uddeholms A.B. — Hagfors
Swedish Mint
S.K.F. Svensk Kulager Fabriken
Surahammers Bruks
Vikmanshytte
Kanthal A.B.

SWITZERLAND

Boillat
Selve — Thun
Dornach
Swiss Mint
Von Roll
Escher Wyss
Sulzer, Winterthur
Schaffhausen Works of Fischer

U.S.A.

INCO — Huntington Alloys, West Virginia and Kentucky
Allegheny Ludlum Industries Inc. — Pittsburgh, Pa.
Armco Steel Corp. — Middletown, Ohio
The Babcock and Wilcox Co., Tubular Products
Division — Beaver Falls, Pa.
Borg-Warner Corp. — New Castle, Ind.
Carpenter Technology Corp. Reading, Pa.
Crucible Stainless Steel Div. of Colt Industries —
Midland, Pa.
Eastern Stainless Steel Co. — Baltimore, Md.
Jessop Steel Co. — Washington, Pa.
Jones and Laughlin Steel Corp. — Pittsburgh, Pa.
Joslyn Stainless Steels – Chicago, Ill.
McLouth Steel Corp. — Detroit, Mich.
Phoenix Steel Corp. — Claymont, Del.
Republic Steel Corp. — Ohio
Simonds Steel Div., Wallace-Murray Corp. —
Lockport, N.Y.
The Timken Co. — Ohio
United States Steel Corp. – Pittsburgh, Pa.

Universal Cyclops Specialty Steel Div. — Pittsburgh, Pa.
Washington Steel Corp. — Washington, Pa.
Wilbur B. Driver Co. — Newark, New Jersey
Driver Harris Co. — Harrison, New Jersey
Teledyne Inc., Cal.
Interlake Steel Corp. — Chicago, Ill.
United States Mint

EAST GERMANY

VEB Edelstahlwerk "8 Mai 1945" — steelworks
VEB Stahl- und Walzwerk Wilhelm Florin — steelworks
VEB Stahl- und Walzwerk Riesa — steelworks
former Krupp-Gruson works at Magdeburg — steelworks

POLAND

Huta Warszawa, near Warsaw — steelworks

CZECHOSLOVAKIA

Trinec Iron and Steel Works — Trinec

YUGOSLAVIA

Jesenice Steelworks
Zelezarna Ravne Steelworks (Est. 1620) Ravne na Koroskem S.R.S.
Zeljezara "Boris Kidric" Steelworks, Niksic, Montenegro

RUSSIA

Soviet Mint
Chelyabinskiy Met. Zavod — steelworks
Met. Zavod Dneprospetstal — steelworks
Electrostal Metallurgechesky Zavod, Imeni Tevosyan — steelworks
Met. Zavod Kuybyshev — steelworks
Verkh-Isetskiy Met. Zavod — steelworks
Zaporozhstal Zavod — steelworks
Zlatoustovskiy Met. Zavod — steelworks

CHINA

Shanghai Works — steelworks
Wuhan Works, Hopeh Prov. — steelworks

Reference: Metal Bulletin 1972, London Stainless Steel.
Iron and Steel Works of the World, London
R. Cordero
R. Serjeanston

2.2.8 MARKETING OF CANADIAN NICKEL

Canadian Nickel is produced and exported or sold in Canada in various Class I and Class II forms and as nickel matte and nickel concentrate.

Market Share
In 1950, Inco had about 85 per cent of the Western World market and Falconbridge had 10 per cent. By 1976, INCO had only 35 per cent, *but Falconbridge held on to its 10 per cent share of the world market* up to the end of 1976, with the aid of the Dominican Republic nickel.

INTERNATIONAL NICKEL (INCO)
For several decades from the 1920's, International Nickel founded and supported Nickel Information Bureaus around the world, mainly in Western Europe and also maintained a large support staff in major consumption areas devoted to the promotion, application and market development of intermediate nickel products, e.g. stainless steels, superalloys, magnets, etc. Advertising and technical promotional literature was aimed at informing potential consumers of the advantages and merits of nickel containing materials developed in INCO's research laboratories in the U.S. and U.K.

Although INCO continues to work on new product development in its research laboratories, its marketing posture changed dramatically in the early 1970's and the emphasis since then has been the attempt to protect market share and maximizing shipments of primary nickel products. The INCO METALS COMPANY DIVISION OF INCO, was created in March, 1977 and is responsible for exploration, mine development, refining and the marketing of all primary Class I and Class II metal products including nickel cathodes, carbonyl nickel pellets and powder, nickel salts, "Incomet", "S" nickel, "Incomag", copper, precious metals and other byproducts. INCO METALS has sales offices around the world (20 countries) and warehouses in strategic locations in North America, Europe and other areas in order to supply primary nickel directly to the larger consumers. INCO also sells to smaller consumers through metal distributors and electro plating supply houses to the smaller consumers who purchase less than 20,000 pounds per order.

The entrance into the market in the 1970's of several new nickel mining and refining companies and the expansion of existing companies into developing countries has led to intense competition and for the past year or so to disorderly pricing. INCO METALS is faced with serious competition, in particular from Class II products (mainly ferronickel and oxide sinter) developed for consumption in the major consuming industries (stainless steels, construction steels, and cast ferrous alloys). Although INCO remains the price leader, (because of its size), by continuously testing the market for reaction to price increases, it nevertheless will not willingly relinquish market share and will therefore match "allowances" and discounts.

INCO Ltd. is the only large primary nickel producer that has captive markets to any degree. A significant portion of INCO nickel is applied in the production of high nickel and superalloys in Huntington Alloys Division, West Virginia and Kentucky, U.S.A., and wholly owned Henry Wiggin Co. Ltd., at Hereford, and Daniel Doncaster Company in the U.K. They also hold significant minority interests in Japan —

(Shimura Kako 30% — ferronickel and electrolytic nickel)
(Tokyo Nickel 40% — nickel oxide)
(Daido Special Alloy Co. — specialty steels
— high nickel alloys)

INCO ships electrolytic nickel, "S" nickel, nickel oxide, nickel powder, nickel matte, from Thompson, Manitoba, Sudbury, Ontario, Port Colborne, Ontario and from the United Kingdom to the Japanese market.

INCO will also supply nickel powder to their new coinage strip rolling mill in the Sudbury District which commenced trials in March, 1977.

P. T. International Nickel Indonesia commenced production mid-1977 (first stage capacity is 15,880 metric tons of nickel in nickel oxide matte) and final completion will complete the 45,400 (nickel contained) metric ton/year project. INCO supply of nickel matte to Japan from Canada will probably cease by early 1978. Further, Exmibal, the INCO-Hanna project in Guatemala will be completed and producing in early 1978 with capacity to produce 12,500 tons of nickel in matte.

The two projects have the capacity to supply most of the requirements of INCO's improved Clydach, Wales, Refinery and this option could affect Sudbury and Thompson production in Canada, particularly during periods of excess capacity. It seems reasonable to assume that INCO METALS plans to dominate the E.E.C. and other Western Europe market share by supply from the Clydach Refinery located inside the E.E.C. — Falconbridge's nickel refinery is *not* in the E.E.C. since Norway did not join; hold market share in Japan through minority interests in producers and consumer companies; retain market share in the Western hemisphere by supply from Canada. The same rationale is applicable with respect to rolled alloys products produced in the U.S.A., Canada, U.K., and Japan.

INCO's nickel deliveries include the following quantities of nickel purchased from others, mainly the *Soviet Union,* at or above market prices and on which INCO made no profit:

1966	55,384 metric tons of nickel
1967	16,411 metric tons of nickel
1968	9,999 metric tons of nickel
1969	4,110 metric tons of nickel
1970	15,003 metric tons of nickel
1971-76	assumed no purchases from others

FALCONBRIDGE NICKEL MINES LTD., TORONTO, ONTARIO, operates a smelter at Falconbridge, Ontario, producing nickel-copper matte (containing cobalt and precious metals) from the ores mined in the Sudbury area and, until 1976, from Manibridge Mine in Manitoba. All nickel, copper and other byproducts are refined at Falconbridge Nikkelverk A/S, Kristiansand S., Norway. The marketing of nickel, copper and byproducts, including nickel salts, was confined primarily to Europe until after World War II.

During World War II, the company's matte was refined in Sudbury by INCO and allocated according to defence requirements in the U.S.A. and Canada. Norway was occupied by the Germans from 1940 to 1945. The refinery in Norway was reactivated in 1946 and sales commenced mainly through agents in Europe and also an agent in U.S.A. The U.S. concern about adequate future nickel supplies resulted in a U.S. Government decision to stockpile nickel and to encourage mine development in politically stable countries and in the U.S.A. The Company was extremely successful in negotiating and securing contracts from the U.S. Defense Material Production Agency as follows:

1948	40 million pounds over 5 years

1951	50 million pounds over 10 years and a $6 million advance for early deliveries
1953 a further	100 million pounds over 9 years 50 million pounds at Falconbridge's option and 50 million pounds in years 10 to 14.

ALSO, a premium of 40 cents/pound above market price for the first 100 million pounds delivered against DMP.60 (the 1953 contract).

It should be noted that INCO and Sherritt Gordon, (whose nickel mine in Canada is now closed), benefitted from DMP contracts as well.

The stockpile contracts enabled Falconbridge to build a major mining and refining complex and launched the Company as a significant primary nickel producer supplier to the U.S.A. Over a period of 10 years, Falconbridge cathode also became known to major consumers through releases from the U.S. G.S.A. stockpile delivered for defence production. Major commercial sales to the U.S.A. and Canada commenced through direct sales. Warehousing of nickel refined in Norway was located near Port Colborne, Ontario, for prompt access to the U.S. market.

Falconbridge International Ltd. and Falconbridge Europe SA were formed in 1971. Sales agents were replaced by direct sales of cathode, "Nickel 98", salts and by-products in most countries in Europe. Falconbridge International (Bermuda) Ltd. and also Falconbridge U.S. Inc., Pittsburgh were formed in 1977 in order to more effectively market all Falconbridge group companies' primary metals and concentrates, with warehouses located in Amsterdam, Holland and Baltimore, Maryland. In North America, Falconbridge has avoided sales through distributors and plating supply houses and in essence ignores the small consumer market, although this may change because of competition.

Falconbridge supplies nickel to Indusmin Ltd. (a Falco subsidiary) (Fahramet Division) Orillia, Ontario, a stainless and alloy steel foundry. Also Armco Steel holds about 25% of Falco Dominicana and there seems little doubt that Falconbridge is a favoured supplier.

2.2.9 CANADA — STEEL INDUSTRY AND FERROUS CASTINGS

The steel and ferrous castings industries consume between 60 and 65% of all primary nickel consumed in Canada. Over 50% is accounted for by the stainless steel and alloy steel mill products producers, (i.e.) Atlas Steels Co., Crucible Steel Division of Colt Industries, Stelco, Algoma and to a lesser extent alloy steel bar producers. Major foundry consumers are Dofasco, Fahramet, Canron, Noranda Foundry Operations, Black-Clawson Kennedy, and Welmet Industries. The estimated consumption pattern of Class I vs. Class II nickel particularly in the stainless and alloy steel segment has been steadily changing and is similar to the U.S.A. pattern. The use of vacuum oxygen decarburization vessels and the availability of nickel oxide sinter and imported ferro nickel has resulted in Class II nickel percentage increasing from 56% in 1969 to 76% in 1972 to an estimated 90% in 1976.

Nickel consumption peaked in 1970 and has increased steadily from the low of 5046 metric tons in 1971. Competition from imported alloy and stainless steel from Europe and Japan has had the effect of containing nickel consumption growth in Canada, as well as changes in the mining industry, construction industry and automotive industry.

2.2.10 OTHER INDUSTRIAL CONSUMPTION IN CANADA

The copper and brass industry including non-ferrous castings uses 3% of nickel consumed in Canada mostly in cupro-nickel alloys as tube sheets and heat exchanger tubing and similar alloys as castings.

The electroplating industry including captive operations in automotive and heating and plumbing products consumes from 15 to 23% of nickel used in Canada. Since 1969 consumption of nickel, including nickel salts, reached a high of 2609 metric tons in 1973. A drop in demand because of a market drop in construction and also in automotive and other consumer product production has seen a drop from 23% of total Canadian consumption to 15 to 16% which is closer to the U.S.A. pattern of about 15%.

Miscellaneous consumption including powder metallurgy, and coinage applications varies between 10 and 20% of consumption. Powder metallurgy applications are expected to grow whereas coinage is dependent upon Canadian demand plus exports from the Sherritt Gordon and Royal Canadian Mints. Also, INCO in Sudbury will be producing nickel and cupro-nickel strip as well which indicates expected growth in such applications.

Consumption of nickel in Canada is generally less than 5% of Canadian nickel shipments. Growth in Canadian consumption is expected to follow Western World nickel demand.

TABLE 2.2.10.1

CANADIAN CONSUMPTION OF NICKEL

(metric tons)

	1969	1970	1971	1972	1973	1974	1975
Steel Industry and Ferrous Castings	6772	8281	5046	5571	6709e	7010e	7180e
Copper and Brass	228	300	253	256	300e	325e	317e
Electro Plating	1820	1670	1846	2389	2609	1898	1736
Miscellaneous	2152	449	642	941	1143e	2337e	2057e
TOTAL	10972	10699	7786	9241	10761	11567	11308

e estimated. Ontario Mineral Resources Branch.

Sources Statistics Canada
MR 157 Nickel
(E M R. Mineral Policy Series)

NICKEL IMPORTS INTO CANADA

1) **Commodity 44199 Ferro Alloys Nes.**

			Tons	Contained Nickel Pounds	Value/Pound
From Greece					
Ferro (25% nickel)	(6 months)	1977	5,511	2,755,500	Can. $2.14
		1976	4,950	2,475,000	2.45
		1975	nil	nil	nil
		1974	8,619	4,309,500	1.60
		1973	18,178	9,098,000	1.27
		1972	nil	nil	nil
From Dominican Republic					
Ferro (35% nickel)		1977	nil	nil	nil
		1976	13,865	9,705,500	Can. $1.99
		1975	5,232	3,662,400	2.21
		1974	3,019	2,113,300	1.46
		1973	4,049	2,834,300	1.41
		1972	938	656,600	1.50
		1971	nil	nil	nil

Total Nickel Contained — Imports of Ferro-Nickel

(6 months)	1977	2,755,500 pounds
	1976	12,180,500 pounds
	1975	3,662,400 pounds
	1974	6,422,800 pounds
	1973	11,923,300 pounds
	1972	656,600 pounds

Assumption: All imports from *Greece* and *Dominican Republic* are Ferro-Nickel.

NICKEL IMPORTS IN CANADA (continued)

2) **Commodity 25859 Imports**

Nickel in Ores, Concentrate and Scrap

		Pounds	Value	Value/Pound of Nickel
(6 months)	1977	38,276,500	$32,128,000	Can. $0.84
	1976	54,159,500	48,567,000	0.95
	1975	39,449,800	45,074,000	1.14
	1974	23,539,600	16,082,000	0.71
	1973	29,117,600	21,724,000	0.75
	1972	51,309,100	39,118,000	0.76
	1971	38,713,800	27,587,000	0.71

3) **Nickel Imports Commodity 454-15**

Nickel Anodes, Cathodes, Ingots and Rods

		Pounds	Value	Value/Pound
(6 months)	1977	591,600	$ 1,189,000	Can. $2.01
	1976	37,100,900	84,238,000	2.27
	1975	28,323,100	58,468,000	2.06
	1974	33,584,400	59,537,000	1.77
	1973	32,282,600	51,101,000	1.58
	1972	35,999,200	51,149,000	1.42
	1971	28,130,900	39,143,000	1.39

Most of the finished nickel above comes from Norway and is re-exported. A few million pounds come in primarily from U.K. and U.S.A., probably as Anodes (special cast shapes) and nickel rod used in temperature controls of water heaters.

1977: Falconbridge, Norway now ships direct to U.S.A and warehouses nickel in Baltimore and Pittsburgh.

Chapter 3 World Mine Production of Nickel

World output of newly mined nickel is estimated to have increased in 1977 by about 35,000 metric tons to almost 780,000 tons, compared to 1976.

OVERSUPPLY SHOULD CONTINUE THROUGH 1980. THE NEW NICKEL PRODUCERS ARE MAINLY *DEVELOPING* COUNTRIES WHICH ARE *RELUCTANT TO CUT BACK* THE OUTPUT OF A COMMODITY THAT ACCOUNTS FOR A LARGE PART OF THEIR FOREIGN EXCHANGE EARNINGS.

ACTUALLY, *LOWER* WORLD NICKEL PRICES ENCOURAGE *HIGHER* MINE OUTPUT IN THOSE COUNTRIES SO AS TO MAINTAIN THEIR FLOW OF TOTAL REVENUE.

Nickel's Ranking among the other metals has grown remarkably
(Value-ranking of World mine production of nickel, U.S. currency)

1973	10th	($1,290 million)
1968	13th	($845 million)
1950	20th	($160 million)

Compared to other base metals, world nickel output has shown phenomenal growth in this century — from just over 6,000 tons in 1900 to 779,000 metric tons in 1976. This surpasses the growth rates of other metals such as cobalt, molybdenum, chromium, etc.

The Ontario nickel mines and the Russian nickel sulphide mines yield generous quantities of the platinum group metals and gold, silver and copper, which greatly help the profitability of those mines. However, the Manitoba and tropical laterite nickel ores contain virtually none of these precious metals or copper.

3.1 World Mine Production of Nickel-Statistics

(Nickel Content of Ore/Concentrates)

	1971	1972	1973	1974	1975	1976E	1980F (capacity)
				(metric tons)			
Canada	267,000	235,000	249,000	269,000	242,000	262,000	249,000
Russia-E	110,000	110,000	110,000	120,000	125,000	130,000	190,000
New Caledonia	151,000	108,000	116,000	137,000	133,000	119,000	140,000
Australia	35,000	35,000	40,000	46,000	67,000	75,000	101,000
Southern Africa (including Botswana and Rhodesia)	24,000	24,000	32,000	36,000	39,000	51,000	64,000
Cuba-E	36,000	37,000	35,000	34,000	37,000	37,000	46,500
Dominican Republic (Falconbridge)	200	17,000	30,000	30,000	27,000	24,000	30,000
Philippines	200	400	400	300	9,000	15,000	46,000
Total Mine Output of Nickel (including sundry countries)	681,000	625,000	674,000	737,000	743,000	779,000E	1.1 million capacity-F

n.b. **Sea Bed Nickel**
Nickel *output from sea bed* nodules in the early or mid-1980's will augment the supply picture.

Source: Metallgesellschaft, except 1980.

E — estimate

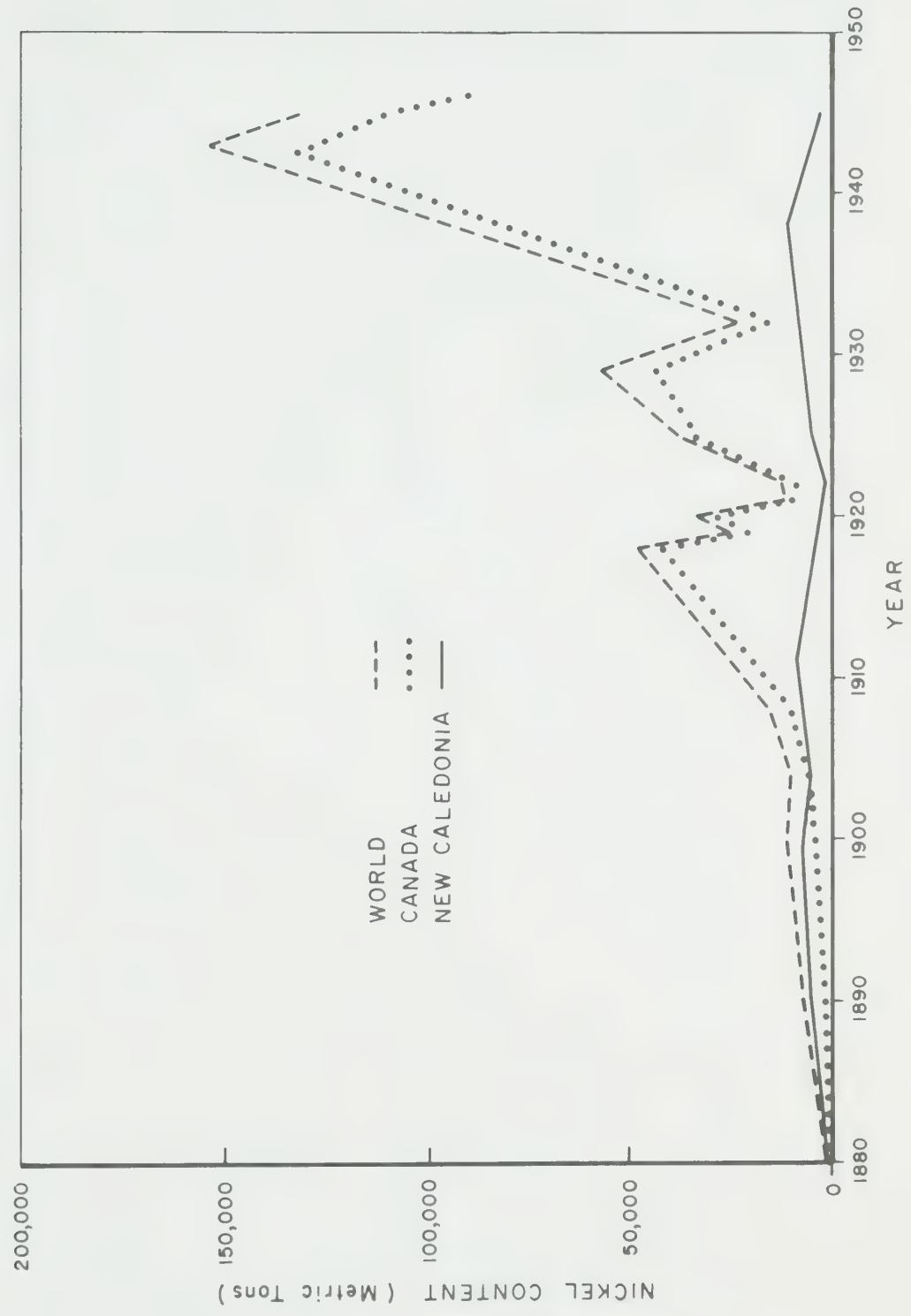
F — forecast

"Mine production" as a rule means the content of the utilizable ores (concentrates) calculated by assay. On the other hand a number of countries, including Germany, publish the recoverable metal content of the ores.

HISTORICAL MINE PRODUCTION OF NICKEL

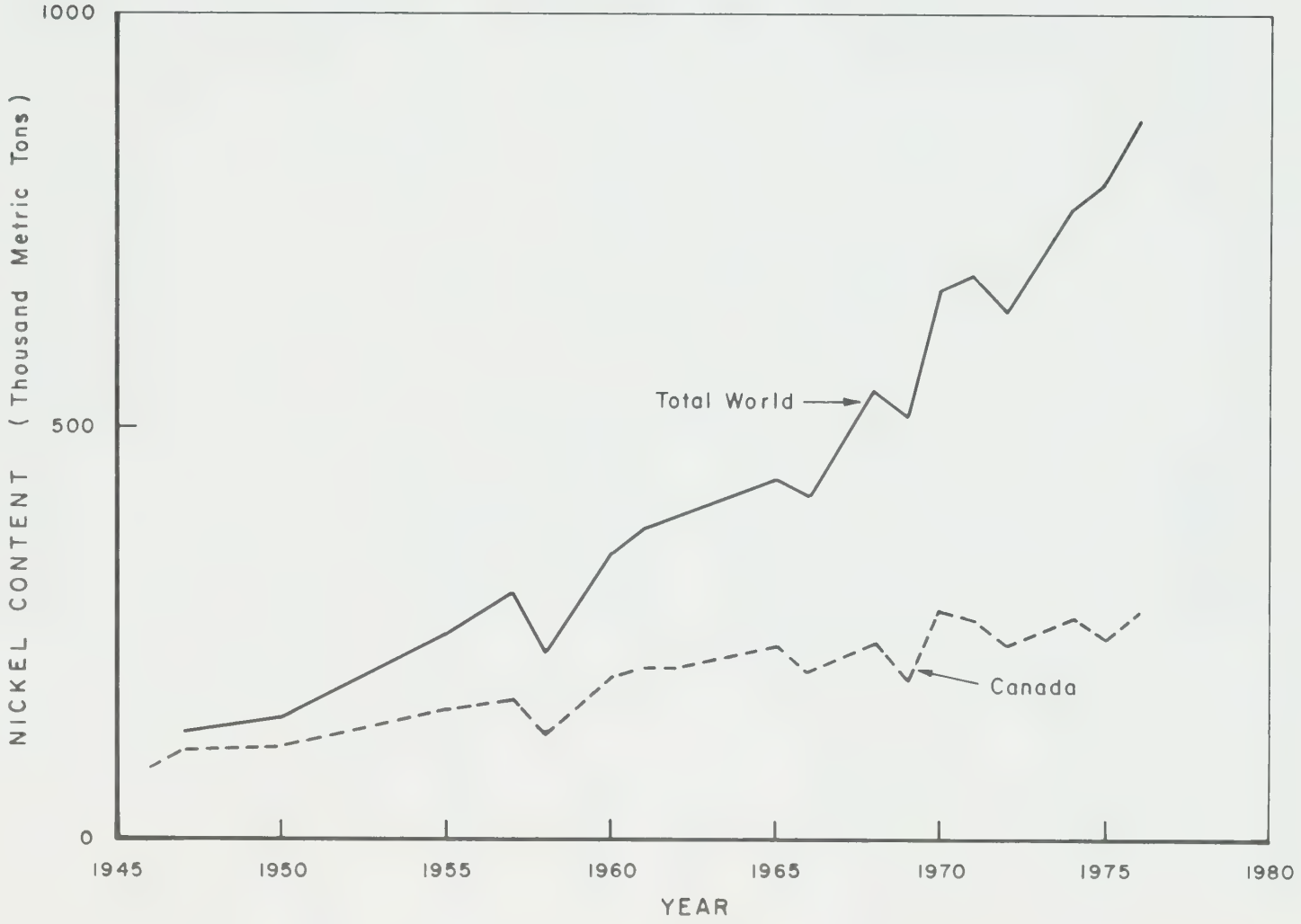
CANADA vs WORLD

1880 - 1945



HISTORICAL MINE PRODUCTION OF NICKEL

CANADA vs WORLD
1945 - 1976



SUMMARY — WORLD

ANNUAL MINE CAPACITY BY END-1980

(metric tons of nickel contained)

		COST (U.S. dollars)
CANADA		
Sulphides		
INCO Metals Company (2 Provinces)	209,000 metric tons	
— Ontario	170,000 metric tons	
— Manitoba	80,000 metric tons	
Falconbridge		
— Ontario	40,000 metric tons	$96 million (for smelter improvement)
CANADA — TOTAL MINE CAPACITY	up to 249,000 metric tons	
FRENCH ISLAND OF NEW CALEDONIA		
Laterites		
SLN (Societe Metallurgique le Nickel)	90,000 metric tons	over $250 million
Penamax (AMAX) (Penarroya interest sold to SLN)	n.a.	n.a.
B.R.G.M.-COFREMI-AMAX (garnierite), 26,000 projected	after 1980	$600 million
Goro (INCO of Canada after 1980) 20,000 projected	after 1980	$275 million est. (in 1974 dollars)
Independents	50,000 metric tons	n.a.
NEW CALEDONIA — TOTAL MINE CAPACITY	140,000 metric tons	
AUSTRALIA		
Sulphides		
Western Mining Corp. (including sundry mines)	45,000 metric tons	n.a.
Windarra (50 per cent owned by Western Mining)	14,000 metric tons	
Agnew	up to 15,000 metric tons	$100 million
Mt. Keith (project) after 1980		n.a.
Others	3,000	
Laterite		
Greenvale	24,000 metric tons	over $300 million
AUSTRALIA — TOTAL MINE CAPACITY	101,000 metric tons	

ANNUAL MINE CAPACITY BY END-1980

(nickel contained)

			COST (U.S. dollars)
ASIA (excluding U.S.S.R.)			
Laterites			
INDONESIA (INCO of Canada, Aneka and Gag Island)	65,000	INCO: Aneka: GAG:	$875 million n.a. $1,000 million
PHILIPPINES	46,000	MARINDUQUE: ATLAS: Rio Tuba:	$282 million n.a. n.a.
INDIA — Sukhinda	5,000 after 1980		400 million rupees
ASIA — TOTAL MINE CAPACITY	116,000 metric tons		
U.S.S.R.			
Sulphides			
Noril'sk-Talnakh, N.W. Siberia	est. 132,000		1,000 million roubles
Pechenga — Kola Peninsula, N.W. Russia	est. 27,000		n.a.
Oxides			
Ural Mountains and the Ukraine	est. 31,000		n.a.
SOVIET UNION — TOTAL MINE CAPACITY	190,000 metric tons		
EUROPE (excluding U.S.S.R.)			
ALBANIA	8,000		n.a.
FINLAND, Sulphides	6,000		n.a.
EAST GERMANY	3,000		n.a.
GREECE	27,000		n.a.
POLAND	3,000		n.a.
YUGOSLAVIA	16,000	FENI:	$170 million
EUROPE — TOTAL MINE CAPACITY	63,000 metric tons		
AFRICA			
Sulphides			
BOTSWANA	19,000		n.a. (from Canada: $25 million for power plant)
ZIMBABWE (Rhodesia)	20,000		n.a.
REPUBLIC OF SOUTH AFRICA (from platinum mines — two partly held by *INCO* and *Falconbridge of Canada*)	25,000		n.a.
AFRICA — TOTAL MINE CAPACITY	64,000 metric tons		

ANNUAL MINE CAPACITY BY END-1980

(nickel contained)

		COST (U.S. dollars)
LATIN AMERICA		
Laterites		
BRAZIL	7,000	n.a.
COLOMBIA	20,000	$300 million
CUBA	46,500	$600 million expansion
DOMINICAN REPUBLIC (Falconbridge of Canada)	30,000	$200 million (1971)
GUATEMALA	13,000	$232 million
VENEZUELA	n.a.	n.a.
PUERTO RICO (U.S.A.)	after 1980	n.a.
LATIN AMERICA — TOTAL MINE CAPACITY	117,000 metric tons	
U.S.A.		
U.S.A. — TOTAL MINE CAPACITY	12,000 metric tons	

WORLD

1. TOTAL "PLANNED" WESTERN AND INCREASED SOVIET AND CUBAN CAPACITY BY 1980: 1.05 MILLION METRIC TONS OF NICKEL A YEAR.
2. INCO ESTIMATE NON-COMMUNIST WORLD NICKEL PRODUCTION TO BE ABOUT 770,000 TONS BY 1980. COMMUNIST WORLD CAPACITY MAY BE ASSUMED TO BE 280,000 METRIC TONS BY 1980.
3. WORLD NICKEL PRODUCTION CAPACITY MIGHT HAVE TO *DOUBLE* THE 1975 LEVEL BY THE YEAR 2000, IF THE MORE OPTIMISTIC FORECASTS OF WORLD NICKEL *CONSUMPTION* PROVE TO BE CORRECT.

Lower world prices for base metals such as nickel actually act as an inducement to developing countries to *increase* mine output not reduce it - because only in this way can such mono-commodity countires generate badly-needed foreign exchange and repay their large debts.

3.2 World Producers of Nickel

MAIN MINES NOW IN PRODUCTION	CAPACITY — MINE PRODUCTION, 1976 (Recoverable Nickel Content)
INCO Ltd., in Ontario and in Manitoba, which is assumed to be 27 per cent of total;	235,000 metric tons p.a., (refined in Ontario, Manitoba and the U.K.).
	(209,000 actual output estimated, 1976).
INCO Ltd., in *Indonesia* and *Guatemala* (laterite ores) (Total cost will be *$1.1 billion*).	30,000 metric tons p.a. (1977); (being expanded).
State mines of the Soviet Union — mainly the Noril'sk/ Talnakh/ Taimir area, (sulphide ores) "Mining Annual Review" estimated.	160,000 metric tons, 1976. (Expansion to 175,000 tons plus is under way.)
SLN company and Independents in (French) New Caledonia. (East of Australia) (laterite ores).	133,000 metric tons p.a. (Expansion under way.)
Western Mining, Greenvale, etc. in Australia (mainly sulphide ores).	60,000 metric tons p.a.
State mines in Cuba (laterite ores).	
Platinum, etc. mines in Southern Africa — total (both *INCO* and *Falconbridge* have interests in nickel output there).	42,000 metric tons p.a. (Expansion to *125,000 tons* under way, completion 1985?)
Dominican Republic, (*Falconbridge*) (laterite).	41,000 metric tons p.a.
Falconbridge in Ontario, Canada (sulphide ores) (refined in Norway).	30,500 metric tons p.a. (1974)
	35,000 metric tons p.a. estimated currently. A 30 per cent cutback in 1976 is not being fully restored.

n.b. BOTH INCO OF CANADA AND FALCONBRIDGE OF CANADA NOW HAVE NICKEL MINES *OUTSIDE OF CANADA.*

Sherritt Gordon, Manitoba, Canada — Nickel mine in Canada now *closed.* (18,000 metric tons p.a. was the peak, *but* output declined to 4,000 tons in 1975.)

INCO estimate total nickel production capacity in the non-communist world at end-1977 to be about 680,000 metric tons of nickel per year. By 1980, this capacity is expected to rise to 771,000 metric tons per year, i.e. *an increase of 34.7%*. INCO's proportion of this capacity is expected to be approximately 267,000 metric tons. We would guess, therefore, that since Indonesia and Guatemala amount to 58,000 metric tons, that INCO's Canadian production capacity estimated by the company would be 209,000 metric tons.

CANADIAN MINE PRODUCERS OF NICKEL IN 1977



– LEGEND –

- ● MINES
- ✱ SMELTERS
- ▲ REFINERIES

1. INCO Ltd. and FALCONBRIDGE NICKEL MINES Ltd., SUDBURY, ONTARIO
2. NORANDA MINES / INCO (LANGMUIR), TIMMINS, ONTARIO
3. INCO Ltd., PORT COLBORNE, ONTARIO
4. INCO Ltd., SHEBANDOWAN, ONTARIO
5. INCO Ltd., THOMPSON, MANITOBA
6. FALCONBRIDGE NICKEL MINES, MANIBRIDGE MINE, MANITOBA

3.3 Canada — Mine Production of Nickel

INCO (the International Nickel Company of Canada) and Falconbridge may be mining the remains of an old asteroid at the Sudbury Basin in Ontario, Canada, or the result of its impact. If you have a nickel or a dime or a quarter in your pocket, it may well consist partly of material from outer space that struck Ontario a half-billion years ago.

The Accident

One of the most important storehouses of natural resource riches for Canada's future was unlocked by accident. It took place at the time when Canada was becoming a nation. Sir John A. Macdonald was doing all he could to bring Western Canada into the Confederation called Canada. He promised to build a railway which would reach right out to British Columbia on the Pacific Coast and the only way to get it through much of the rocky wildnerness in Northern Ontario was to blast a way with explosives. As the track for the new Canadian Pacific Railway was being cleared near Sudbury in 1883, an Irish worker, Tom Flanagan, struck the capping on the top of massive pyrites with his pick. This area became the Murray nickel mine. F. B. Howard White relates that this was at a spot only a few miles from the place where nickel ore had been reported twenty-seven years before.

Present Situation

The Ontario nickel industry is now the world's largest nickel production complex and is Ontario's largest mineral producer. Nickel is Ontario's most important mineral product. Ontario has supplied about 30 per cent of the world's nickel consumption. It is currently suffering from a massive accumulation of inventory of finished metal as a result of the recent world recession and of lower than anticipated rates of growth of consumption in major markets. *Canada consumes very little nickel.* Unless world consumption of nickel improves rapidly in the near future, *it is difficult to see how further cuts in Sudbury region mine and refinery output can be avoided.*

Potential growth of total nickel mine output in Canada is held up and either *no overall growth* or a permanent reduction in nickel mining output in Canada are strong possibilities.

There is general acceptance of the need for government regulation to ensure better standards with respect to such matters as environmental preservation, health, safety and proper use of funds raised from the public. It must be recognized, however, that the extra costs imposed on mining operations by new government standards on environmental matters, land use legislation, Workmen's Compensation Board rules, Unemployment Insurance costs, Ontario Securities Commission rules on junior companies and the total tax load represent a growing "governmental" burden. This reduces profit potential, after tax return on capital, and thus availability of investment capital for production maintenance and expansion. Care must be taken to see that this governmental burden is not made larger than absolutely necessary.

Certain Federal, provincial and municipal permits and authorization requirements add to the lead time for new projects, thus imposing significant front-end opportunity costs. Delays may be as much as 2 years for small and 5 to 7 years for big projects.

Constant review is needed to ensure that some of these regulations are not doing more harm than good.

Potential future production of nickel and copper from the sea bed in the 1980's has a distinctly adverse effect on long range planning for land-based production. Such investments in the sea bed are currently considered to be a good business risk.

All Ontario nickel mine operations produce copper, cobalt and most of the precious metals as by-products. INCO also produces iron oxide pellets. Cobalt sells for more than twice the nickel price.

Origins of INCO and Falconbridge

In the mid-1880's, prospectors rushed into the Sudbury area to stake claims, and several mines were started.

It looked at first as if the Sudbury mines would have to close down right after they opened. Nickel smelting commenced in Sudbury about 1890. The first batch of ore that was smelted down did not produce pure copper at all. Instead, it contained a large quantity of nickel. In spite of a few uses that had been found for it, nickel was not in big demand in those days and was therefore thought of chiefly as a nuisance rather than a valuable metal — because it was difficult to separate from the copper. The Sudbury mines asked themselves whether it was possible to find a new way to separate the nickel and develop new uses for it and therefore make it valuable.

It was found that separating the nickel from the copper was so expensive that it cost more to produce the nickel than anyone was willing to pay for it. Experiments went on for months and finally an economical separation process was discovered. This was the successful Orford process. The discovery that mixing nickel with iron in the making of steel made steel much tougher than any steel produced before resulted in manufacturers finding uses for this new, tough steel — particularly in armour plate for warships.

By 1902 the Canadian mines were producing 5,000 tons of nickel annually. The industry was growing at such a rate that finally the Canadian Copper Company at Copper Cliff, Ontario and the refinery in New Jersey in the United States, (where the Canadian ore was refined in those days), decided to amalgamate, and that was the beginning of the International Nickel Company, (incorporated in New Jersey, U.S.A. as The International Nickel Company of Canada, Limited, now known in Canada as the Inco Metals Co. Division of INCO Ltd.). It was formed in 1916 as a subsidiary of the New Jersey company. In 1928 it became the parent company. Today it still produces more nickel than any other company in the world.

In 1920, Canada produced 88 per cent of the world's nickel output.

Norway's nickel mines, dating from the previous century, ceased production finally in 1921 and the idle nickel refinery at Kristiansand was eventually sold at the beginning of the next decade to *Falconbridge of Canada* which was opening a new nickel mine in Ontario.

World mine production of nickel in 1925 was:

	1925 (metric tons nickel content of ore)
Canada	32,972
French New Caledonia	3,320
U.S. (by-product of copper refining)	243

1970 to 1976 — CHANGES

As recently as 1970, Canada's position in the production of nickel in ore in the Western World was as follows:

Canada	289,400 metric tons
French New Caledonia	103,870 metric tons
Australia	26,760 metric tons
Europe (excluding U.S.S.R.)	13,150 metric tons
U.S.A.	12,250 metric tons
Others (Africa, Indonesia, Latin America, Philippines)	21,320 metric tons

The 1976 figures show great changes in this pattern (see table).

Capital costs of a new integrated operation in Canada were estimated at end-1976 at $7 per pound of annual nickel capacity.

There is *a narrowing margin of profit on mining base metals in Canada,* owing to increasing environmental equipment costs and other capital costs, rising rates, higher energy costs and higher taxes on mining operations etc. Class II nickel is the normal product of the lateritic mines in the tropics. It sells for a lower price than Class I nickel but is equally suitable for use in the most important consumption sector (stainless steel production).

A higher and higher proportion of world mine production of nickel is shifting to developing nations which enable industry to recover investment in a very short time. The new nickel projects in Guatemala, Indonesia, Philippines, Botswana, Queensland, etc. now coming into production must sell nickel at any price, if only because of the rigid loan repayment schedules of these ventures, which cost hundreds of millions of dollars each. Russia and Cuba are also greatly increasing their nickel production and exports.

Also, sales volumes and prices offered by Russia and Cuba are governed primarily by considerations of debt servicing to Western creditors and by foreign exchange requirements to pay for imports, particularly in years of bad harvests. This increase of supply must create increased problems for Ontario producers.

For the time being, the mining and processing of nickel from Ontario's and Manitoba's sulphide-type nickel ores is less costly than for the increasing number of lateritic ore mines.

Higher energy costs have improved the competitive position of Ontario nickel sulphide ores, since relatively less energy is used in refining them than is necessary for the laterite ores found in many of the new projects.

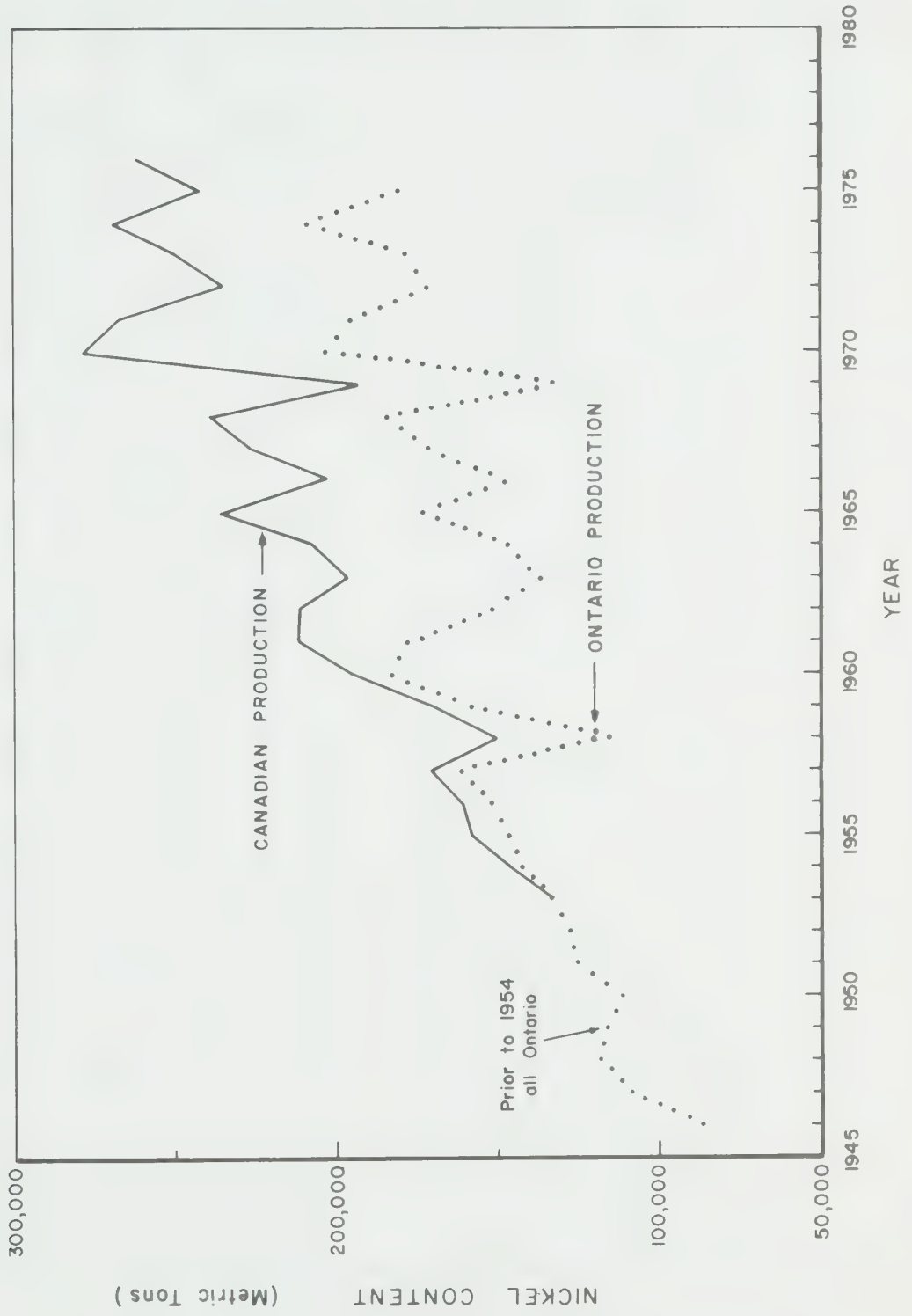
TABLE 3.3

TOTAL MINE PRODUCTION OF NICKEL IN CANADA

Year	Metric tons	Value ($)
1950	112,181	112,104,685
1951	125,104	151,269,994
1952	127,513	151,349,438
1953	130,356	160,430,098
1954	146,310	180,173,392
1955	158,692	215,866,007
1956	161,946	222,204,860
1957	170,513	258,977,309
1958	126,606	194,142,019
1959	169,235	257,008,801
1960	194,597	295,640,279
1961	211,366	351,261,720
1962	210,686	383,784,622
1963	196,886	360,392,658
1964	207,288	379,320,510
1965	235,126	430,402,105
1966	202,856	377,479,471
1967	225,569	463,139,703
1968	239,822	528,235,798
1969	193,786	481,055,140
1970	277,491	830,166,823
1971	267,023	800,064,068
1972	234,949	717,485,105
1973	249,047	813,100,951
1974	269,070	974,594,029
1975	242,200	1,100,522,780
1976p	262,491	1,232,143,000
1977p	n.a.	1,190,000,000

Source: Statistics Canada

CANADIAN and ONTARIO NICKEL PRODUCTION



3.4 Ontario — Mine Production of Nickel-Statistics

Year	Nickel Production[1] (Nickel Content)	Tonnage of Ore Milled (Nickel-Copper mines)
	(metric tons)	
1976		n.a.
1975	179,095	17,399,994
1974	209,051	20,514,560
1973	178,395	19,159,284
1972	171,846	18,477,550
1971	195,728	25,296,364
1970	203,441	24,363,198
1969	133,157	17,005,212
1968	184,836	23,513,370
1967	172,419	19,100,928
1966	145,344	16,367,385
1965	173,530	19,493,142[2]
1964	147,049	19,936,712
1963	135,252	16,699,767
1962	151,121	15,724,683
1961	178,006	18,896,447
1960	182,934	19,002,040
1959	157,818	16,554,454
1958	115,343	11,735,895
1957	160,932	16,474,142
1956	152,023	15,798,970
1955	146,203	14,260,466
1954	143,344	16,124,184
1953	130,356	14,881,098
1952	127,513	14,370,126
1951	125,104	12,870,547
1950	112,182	9,787,168
1949	116,745	9,906,412
1948	119,512	10,591,341
1947	107,616	10,113,248
1946	87,146	7,452,372

p preliminary

(1) Refined metal and nickel in oxide and salts produced plus recoverable nickel in matte or speiss and in ores and concentrates exported.

(2) Represents the tonnage of crude ore smelted, together with the tonnage of ore milled (1946-65).

Sources: Annual Reports of the Ontario Department of Mines; (1946-65), Ontario Mineral Review; (1966-75).

Nickel-Production includes:

a) Refined and electrolytic nickel produced at Canadian refineries, valued at the average price obtained for such products sold during the year.

b) Nickel in nickel oxides and in nickel salts sold from Canadian smelters and refineries during the year at the total selling value of these products.

c) Nickel in matte shipped for export from Canada valued at an arbitrary figure agreed upon by the Ontario Division of Mines and Statistics Canada. This price is a few cents under the Canadian price for the metal and represents as close an approximation as possible to a fair value of nickel in the matte form after allowing a margin for treatment of this matte in refineries outside Canada.

d) Recoverable nickel in concentrates shipped from other provinces to smelters in Ontario or refinery in Alberta valued at an arbitrary price.

3.5.1 VALUE OF ONTARIO-MINED NICKEL SOLD

(Statistics Canada Figures)

	Value (Canadian $)	Quantity (metric tons)
1977	$932,000,000p	184,983p
1976	$882,300,000p	187,451p
1975	$811,328,714	179,095
1974	$749,782,101	209,051
1973	$574,786,081	178,395
1972	$519,935,356	171,846

p preliminary

In terms of "constant" (1971) dollars, the average "value of a pound of nickel in the 1967-71 period was about $1.18 and about $1.31 in the 1971-76 period".

Between 6 and 6.5 per cent of the value of the total output of all metals recovered from ores from Ontario's nickel mines consists of the eight precious metals, (gold, silver, platinum, palladium, rhodium, etc.).

3.5.2 ONTARIO — MAIN NICKEL PRODUCERS

The two principal nickel producers in Ontario, INCO Ltd. and Falconbridge Nickel Mines, both have their main Ontario operations centred around the City of Sudbury in the Sudbury Basin.

INCO Limited, is by far the largest Ontario producer of nickel. As of September, 1977 it operated, or had on a standby basis, twelve underground mines and one open pit within a forty mile radius of Sudbury. The nickel-copper ore mined is found within an elliptical ring 17 miles wide and 37 miles long. The Sudbury district contains a wide range of sizes of ore bodies and mine production rates.

INCO mines the largest and richest copper-nickel orebody in the world, which is known as the Frood-Stobie complex. The Frood-Stobie orebody was discovered in the 1880's and the mining complex is located near Sudbury's northern city limits on the Frood Road. Ore has been mined here both on surface, by open pit methods, and underground via extensive shaft workings. The open pits were developed in 1939 and yielded substantial ore for many years, but this near-surface source was entirely depleted by 1961 and now all production comes from underground. The production rate is currently about 21,500 tons per day, making it one of the world's largest underground mines. In 1978 production from the Stobie portion will be reduced.

One mile north of the Frood-Stobie complex is the *Little Stobie*, a large new mine containing a separate nickel-copper ore body of marginal grade. Production commenced in 1971 and is now in the order of 3500 tons per day of ore.

Mining at *Creighton*, located on Highway 535, about 17 miles west of Sudbury, is carried out through three shafts. The #9 Shaft is 7,138 feet deep and as such, is the deepest *continuous* mine shaft sunk from surface in the Western Hemisphere. Two other shafts are used to bring the Creighton ore to surface.

Production was recently suspended at No. 3 shaft. The Garson Mine operates via a #2 shaft extending from surface and a winze (i.e. an internal shaft). This mine is located on Highway 541 en route to the airport and very close to Falconbridge Nickel in the Town of Falconbridge. Production at the *Kirkwood Mine* near Garson, Ontario was suspended as of 1971.

The Nickel carbonyl refining process was developed by Dr. Ludwig Mond and Carl Langer in England in 1890. Mond had come to England from Germany. He founded the Mond Nickel Company, (which was merged into the International Nickel Company of Canada Ltd. in the late 1920's). The Mond Nickel Company's smelter and sulphuric acid plant were at Coniston, 8 miles east of central Sudbury, Ontario and the Mond-Langer process carbonyl nickel pellet refinery in South Wales at Clydach was opened in 1902 to treat the Ontario ore.

Dr. Mond's associates in the company in England were the first to discover a commercially viable method of recovering platinum group metals from the Sudbury, Ontario nickel-copper ores. A platinum group metals refinery was set up by Mond at Acton, London, England in the 1920's, which continues to be dependent on Ontario feed.

Due west of the Falconbridge area on the opposite side of the Sudbury Basin is located the *Levack Mine* of INCO. This had a production rate of 5,700 tons per day in the fall of 1977 versus a stated capacity, as of December 31, 1974, of 9,000 tons per day. Levack is one of INCO's oldest operating mines and its development has entailed an agreement covering the mining of an orebody which lies partly within Levack and partly within the adjoining Fecunis property of Falconbridge Nickel Mines. In this agreement INCO is doing the development and mining and delivering the ore to the company from whose property it originates. *Levack West* is a new mine which went into production in January, 1974 with the designed daily capacity of 4,000 tons of ore per day. This is developed by a 9,000 foot ramp driven from surface to the mine workings and is therefore a divergence from conventional mining. Current operating rate is approximately 3,600 tons per day, and it connects with the nearby Levack Mine via a 1½ mile long tunnel on the 1600′ level.

THERE ARE VERY FEW CANADIAN NICKEL EXPANSION DEVELOPMENTS WHICH CAN BE CITED, ASIDE FROM THE DISCOVERY IN MONTCALM TOWNSHIP, ONTARIO NEAR TIMMINS. DURING 1976, INCO CONTINUED DEVELOPMENT WORK ON TWO MINES, LEVACK EAST AND THE CLARABELLE OPEN-PIT EXTENSION, BOTH OF WHICH ARE IN THE SUDBURY AREA. THE LARGE *LEVACK EAST* PROJECT HAS BEEN SCHEDULED TO BEGIN PRODUCTION IN 1983, A YEAR EARLIER THAN ANTICIPATED. THE CLARABELLE OPEN-PIT WAS CLOSED IN DECEMBER 1974 AND THE EXTENSION IS EXPECTED TO RESUME PRODUCTION IN 1978.

The *Coleman Mine* is located in the general area of Levack and is one of the larger producers in the Sudbury area. Production commenced in 1971. This mine features INCO's second tallest head frame in the Basin which reaches a height of 227′.

Back on the southeast rim of the Sudbury Basin the *Murray Mine* is located on the western boundary of the City of Sudbury. It is original INCO property discovered in 1883 coincident with the CPR railway construction through the Sudbury district. Operations at Murray have been suspended since 1971 when it was placed on a standby basis. Nearby, the *Clarabelle Open Pit* operates from an ore outcropping southwest of the Murray Mine. This is known as the #2 Open Pit and the production rate is in the order of 5,000 tons per day. The *Copper Cliff North Mine* is the underground portion of the Clarabelle ore body and was developed through one 4100′ shaft with production commencing in mid-1970. It is currently operating at a rate of approximately 7,500 tons per day but operations are slotted to cease in 1978. The *Copper Cliff South Mine* is located near the Copper Cliff Smelter and was developed via two shafts with a total operating rate of 6,000 tons per day.

Crean Hill production rate is about 4,500 tons per day. It began in early 1964 and reached 3,000 tons capacity during the fourth quarter of that year climbing to about 3,800 tons by the end of 1971. Production was suspended in early 1972 but resumed in January, 1974. Operations will be suspended in mid-1978.

The *MacLennan Mine* was originally developed by an open pit in 1965-66 and subsequently by shaft and underground workings. Operations ceased in 1972 when the ore was exhausted. MacLennan is located almost due north of the Falconbridge operations at the east end of the Basin. The *Totten Mine* is located near the Town of Worthington on the southwest end of the Sudbury Basin. It was suspended in March, 1972 but is being maintained on a standby basis. Capacity of their #2 Shaft is about 1,500 tons per day.

The Victoria underground mine ceased production in 1923 but has since been reactivated with regular production coming on-stream in 1974. This is the one which will be closed permanently.

Interwoven with the Sudbury area INCO operations are those of *Falconbridge Nickel Mines Ltd.* The *Falconbridge Mine* is the original operation of this company and was producing from one shaft and a winze at the rate of about 3,500 tons per day, being located right within the Town of Falconbridge on the east side of the Sudbury Basin. This property was originally owned by the Longyear family of Michigan, later acquired by Bennett interests of Minneapolis and, in 1928, by Ventures Limited, the predecessor of the current company. The *East Mine* is located 4500′ east of the #5 Falconbridge Mine Shaft. It operated from late 1954 to late 1975 when it was placed on standby.

Falconbridge's *Onaping* and *Hardy* mines are located to the southwest of INCO's Levack West property. While the Onaping Mine was closed in 1976 and the Hardy underground operations have terminated, the Hardy Open Pit Mine closed in 1977. To the northeast of these developments are located the Coleman operation of INCO, and the *Longvack, Strathcona, Fraser,* and the *North Mine* properties of Falconbridge. The *Fecunis (FeCuNiS) Lake Mine* straddles INCO's Levack property. In 1958, INCO took over the entire mining operation of these two latter properties, with ore mined from Falconbridge Nickel ground being delivered to the Fecunis shaft for hoisting and subsequent treatment. Ore delivered from the Fecunis Lake property was treated at the mine's concentrator which was completed in 1957. In late 1975 operations were reduced to 5% of the normal rate and was placed on standby in 1977. The North Mine will be closed in 1978.

The Strathcona Mine is located between the Fecunis Lake and Longvack Mines. The Strathcona Mill was completed in 1968 and reached production capacity in 1969. In early 1975 the mill was expanded to accommodate ore from the Lockerby Mine.

The *Longvack South Mine* is situated north of the Strathcona Mine and separated by two claims not owned by Falconbridge. While full scale production was attained in October, 1968 with

ore being treated at the Strathcona Mill, the mine was placed on standby and closed in 1977. The *Fraser* area is located between the Strathcona and Fecunis Lake Mines. It is considered to have a large ore potential. The Fraser Shaft was collared in 1970, and construction of the surface plant was largely completed by the 1970 year-end. However, the Fraser Shaft development program was deferred from late 1971 until July, 1973 when shaft sinking was resumed. Sinking was suspended again in August, 1975 at which time the 5,565′ shaft was 84% completed. During 1975 an exchange-of-ore agreement involving the Fraser orebody was signed with INCO to permit the more efficient mining of an orebody which crosses the boundary between certain Falconbridge Nickel claims. Sinking of the ventilation shaft and other pre-production work at the Fraser mine is being deferred as part of the current cost reduction program.

The *Lockerby* property is located in Denison Township, about 20 miles west of the City of Sudbury, close to the Crean Hill operation. Development of this property started in March, 1969 and by the end of 1975 the mine was producing 16,000 tons per month. It was scheduled to operate at 25% of its designed capacity in 1976, moving toward full capacity in 1978. However in December of 1977 production was suspended.

The *Lindsley* property is located to the northeast of the Little Stobie Mine and was to be brought into production by early 1974 at a rate of 1,750 tons per day. However, development of the program was deferred in late 1971 and has not been resumed to date.

Therefore, it can be seen that throughout the whole Sudbury Basin the mines of Falconbridge Nickel and INCO are intertwined. Development has undoubtedly been held back in many cases because of the complexities of land tenure. This can be expected to have the worst effect in the Levack area.

Another INCO Ontario operation is the *Shebandowan Mine* located in northwest Ontario near Thunder Bay. This is an underground operation, smaller in size than many of the Sudbury properties but having a richer orebody. The underground operation is 2,000 tons per day on a five day week basis. The nickel-copper ore is concentrated in a mill on the property and shipped via CP rail to Sudbury for smelting. It is interesting to note that the upper part of the orebody, i.e. the crown pillar, is significantly higher in grade than the part of the orebody currently being developed and mined. However, it is impossible to exploit this section of the orebody unless Lake Shebandowan is drained. This is not possible, however, owing to local environmentalists' pressure, even though the Lake is only 25′ deep.

INCO has six mills in total in Ontario, including Shebandowan. The newest is the Copper Cliff Clarabelle Mill which was built in 1971 at a cost of $80 million. This mill has a design capacity of 35,000 tons per day and handles ore delivered in rail cars from various INCO mines. This huge milling complex treats ore from virtually all of INCO's Sudbury operations. It is a completely automated mill and the ore requires no blending prior to concentrating. The product discharged is a nickel concentrate which contains 10% nickel and 2% copper plus a copper concentrate of 30% copper and 1.5% nickel. In addition, a pyrrhotite concentrate containing less than 1% of both nickel and copper is pumped to the company's iron ore recovery plant. The Frood Stobie Mill is another important complex which is located on that property and has a capacity of 24,000 tons per day. This was opened in November, 1967. The company has active concentrators located at Levack and two in the Copper Cliff area. In addition, the Creighton complex mill located 7 miles west of Sudbury was put on standby in 1972.

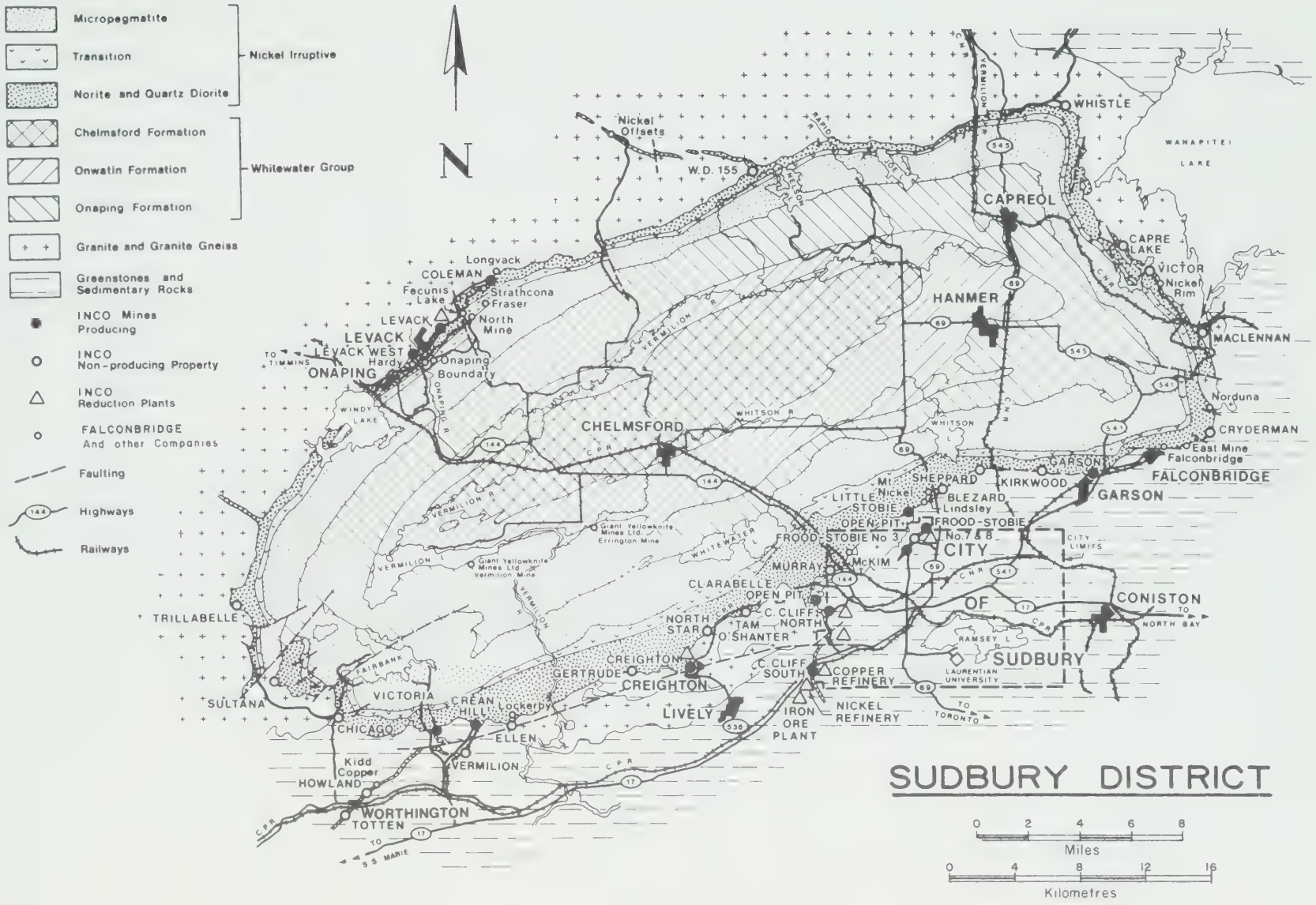
In total, INCO's Ontario Division Concentrators mill a combined average of 52,000 tons per day of ore. It can be seen that there is an effort being made to reduce the number of smaller, inefficient concentrators and replace them with large, fully integrated and automated complexes.

Langmuir Nickel Mine

The joint underground venture of INCO Ltd. and Noranda Mines Ltd. at Timmins, Ontario which came on stream in June, 1973, is to close down by March, 1978. Increased costs and poor results are blamed. Output was refined by INCO.

Future Expansion and New Developments

A copper-nickel discovery 35 miles NW of Timmins, Ontario is being examined by Metallgesellschaft and Teck.


LEGEND
Micropegmatite
Transition
Norite and Quartz Diorite
Nickel Irruptive
Chelmsford Formation
Onwatin Formation
Onaping Formation
Whitewater Group
Granite and Granite Gneiss
Greenstones and Sedimentary Rocks
INCO Mines Producing
INCO Non-producing Property
INCO Reduction Plants
FALCONBRIDGE And other Companies
Faulting
Highways
Railways
N
Nickel Offsets
W.D. 155
WHISTLE
WANAPITEI LAKE
CAPREOL
CAPRE LAKE
VICTOR
Nickel Rim
HANMER
MACLENNAN
Norduna
CRYDERMAN
East Mine
Falconbridge
FALCONBRIDGE
GARSON
SHEPPARD
KIRKWOOD
Mt Nickel
LITTLE STOBIE
BLEZARD
Lindsley
FROOD-STOBIE
OPEN PIT
FROOD-STOBIE No 3
No.7 & 8
CITY
CITY LIMITS
McKIM
MURRAY
CLARABELLE
OPEN PIT
C. CLIFF NORTH
O'SHANTER
TAM
NORTH STAR
CONISTON
OF
SUDBURY
RAMSEY L
LAURENTIAN UNIVERSITY
CREIGHTON
GERTRUDE
C. CLIFF SOUTH
COPPER REFINERY
NICKEL REFINERY
IRON ORE PLANT
LIVELY
TO TORONTO
TO NORTH BAY
Longvack
COLEMAN
Fecunis Lake
Strathcona
Fraser
North Mine
LEVACK
LEVACK WEST
Hardy
Onaping Boundary
ONAPING
TO TIMMINS
WINDY LAKE
CHELMSFORD
WHITSON R
WHITSON L
Giant Yellowknife Mines Ltd Errington Mine
Giant Yellowknife Mines Ltd Vermilion Mine
VERMILION R
WHITEWATER L
TRILLABELLE
SULTANA
FAIRBANK
VICTORIA
CREAN HILL
Lockerby
CHICAGO
ELLEN
VERMILION
Kidd Copper
HOWLAND
WORTHINGTON
TOTTEN
TO SAULT STE MARIE
SUDBURY DISTRICT
0 2 4 6 8
Miles
0 4 8 12 16
Kilometres

3.6 By-Products and Co-Products of Canadian Nickel Mines

The original interest in the Sudbury Basin, Ontario sulphide ores was the discovery of what appeared to be rich copper ore deposit which eventually led to the mining of the ores in order to produce copper and nickel. Most nickel-containing sulphide ores are found in association with iron sulphide and copper. The Canadian ore also contains platinum, palladium, iridium, osmium, rhodium, ruthenium, gold, silver, selenium and tellurium, and, of course, sulphur. All of these metals are recovered to some extent during the smelting and refining of nickel and copper.

The total value of by-products produced each year is a significant portion of the total value generated by the nickel-copper mines in Canada. It amounts to between 26.0% and 35.0% of the total dollars produced. Depending upon the year under discussion, it can be highly important to the nickel-copper producer with respect to net profit generated.

Copper

In aggregrate dollar terms, the second most important co-product of Ontario's nickel mines is copper. INCO LTD. IS CANADA'S LARGEST SINGLE PRODUCER OF NEWLY MINED COPPER. COPPER PRICES HAVE REMAINED AT VERY LOW LEVELS.

The gloomiest world price outlook for any commodity is probably that for copper, in spite of its status as a major foreign earner for Canada.

INCO and Falconbridge are substantial producers of copper from nickel-bearing ores mined in Canada, primarily those mined in Ontario. INCO sells its copper in Canada at the Canadian equivalent of the United States producer price, and abroad at prices based on the London Metal Exchange daily spot quotations for wirebars.

Value of Ontario's Mine Output of Precious Metals

Ontario's total annual mine output of eight precious metals, (gold, silver and platinum group metals combined), is similar to or greater in value, ($270 million in boom year 1974; $255 million in 1975 and $206 million in 1976), compared to total iron ore production and approaches the value of zinc production from mines in Ontario. (Stats. Canada figures.)

Virtually all of Ontario's output of platinum group metals arises as a by-product of the nickel mines, as does a considerable proportion of the gold and silver output.

Ontario is the world's third largest mine producer of platinum group metals and (as Canada's leading gold-producing Province), helps to make Canada the world's third largest mine producer of gold. Each year, Canada vies with Mexico for the position of the world's largest mine producer of silver and Ontario is the leading Province in silver output.

Platinum Group Metals

Canada (Ontario) was, for the 20 years through 1953, the leading world mine producer of the platinum group metals. Canada (*Ontario*) is now the world's third largest mine producer of platinoids, of which the element platinum itself represents less than 50%. As in Russia, the output is a by-product of the nickel-copper mining.

INCO and Falconbridge are major producers, primarily from Ontario ores, of five of the expensive platinum group metals — platinum, palladium, rhodium, ruthenium and iridium. These metals are consumed principally for industrial uses. NONE OF THIS OUTPUT IS REFINED TO METAL IN CANADA. THIS IS DONE FOR CANADA IN ENGLAND, NORWAY AND THE U.S.A.

World demand is forecast by the U.S. Bureau of Mines, after a careful survey, to grow to 375 metric tons of P.G.M.'s a year in 23 years' time, from the level of 175 tons of P.G.M.'s in 1974-75, i.e. more than doubling in about two decades. This expansion in demand will presumably require more P.G.M. refineries or expanded capacity. No major P.G.M. refineries are presently under construction anywhere in the world.

The platinum group metals, gold, silver and copper are subject to volatile changes in price, depending upon demand and future trading.

Other Metals and Special Metals

INCO and Falconbridge also produce limited quantities of cobalt, sulphur, selenium and tellurium. Cobalt has been in very strong demand recently and the price has increased markedly.

Falconbridge Nickel, in recent years has produced as much as 2.5 million pounds of cobalt a year from its Norwegian refinery. The rise in unit prices over the past several years coupled with an increase in output, has resulted in an increase in cobalt revenues from $2.675 million in 1972 to $8.597 million in 1976.

Current price is about $5.50 per pound with some market analysts suggesting short term price increases to $7.50 per pound might be possible. This could add about $10 million to annual revenues, depending on production levels, net sales price, and other variables. Therefore, this commodity is one which may assist the company to some extent in withstanding th current nickel market recession. Deep sea nodule production could put a glut of cobalt on the world market in the 1980's, however.

Mini Steel Mill/Iron Ore

Iron ore pellets produced at the INCO iron ore recovery plant at Copper Cliff, Ontario are sold in the United States and Canada.

There are several processes now in use around the world in which natural gas, bituminous coal, lignite or anthracite coal is used in the direct reduction of iron ore to yield reduced iron pellets. The pellets can be charged directly into an electric arc melting furnace and produce steel.

A mini steel plant producing 500,000 metric tons of steel bars and light structural shapes would employ about 700 persons. The generation of pyrrhotite from INCO and Falconbridge Sudbury area operations could be used as feed for direct reduction kilns. Although Falconbridge was not successful in operating a kiln, there have been considerable new and successful applications in the past few years in Europe, U.S., New Zealand, South Africa.

A conventional mini steel mill was considered for the Sudbury district about 1975 in which scrap steel would have been the prime furnace charge. The project was shelved because of economic conditions at the time. When it is realized that Canada is a net importer of steel scrap most years, and that the Sudbury area generates potential charge material for an electric furnace steel mill plant, it seems logical that the feasibility of a direct reduction plant feeding a mini steel mill should be investigated in depth.

Summing Up

The many uses and applications affecting demand for the by-products would require a lengthy addition to this publication. The salient fact is the magnitude of the significant dollar contributions the by-products give to total profitability of nickel-copper mines in Canada. A reduction in mine production because of nickel inventories can have the effect of reducing total sales depending upon the prices and demand of the by-products. In other words, a reduction of 20% in nickel production also results in approximately a 20% reduction in by-products which may be in good demand and therefore saleable. It has the further effect of providing other suppliers of the by-products, (mainly South Africa and the Soviet Union), with the opportunity to gain and hold a greater market share.

TABLE 3.6

BY-PRODUCT PRODUCTION OF CANADIAN NICKEL-COPPER MINES

Statistics Canada
Catalogue 26-211

3.6.1 PLATINUM GROUP METALS

Year	Kilograms	Value $ Can.
1961	13,008	24,534,349
1962	14,641	28,848,637
1963	11,122	22,585,205
1964	11,701	25,404,117
1965	14,403	36,109,799
1966	12,319	32,370,064
1967	12,481	34,668,915
1968	15,113	46,199,718
1969	9,655	30,881,016
1970	15,005	43,556,597
1971	14,779	39,821,616
1972	12,630	34,656,545
1973	11,018	41,993,743
1974	11,963	60,794,030
1975	12,417	56,493,077

3.6.2 GOLD

Year	Kilograms	Value $ Can.
1961	1,865	2,126,749
1962	1,775	2,135,438
1963	1,672	2,029,100
1964	1,644	1,995,314
1965	1,963	2,380,096
1966	1,855	2,249,326
1967	1,637	1,986,330
1968	2,026	2,456,429
1969	1,311	1,588,558
1970	1,757	2,065,567
1971	2,050	2,329,770
1972	1,834	3,396,337
1973	1,642	5,142,087
1974	1,758	8,776,667
1975	1,578	8,307,627

3.6.3 SILVER

Year	Kilograms	Value $ Can.
1961	56,102	1,700,395
1962	55,346	2,073,256
1963	43,475	1,934,743
1964	46,926	2,112,438
1965	57,244	2,576,941
1966	53,210	2,393,327
1967	52,693	2,934,188
1968	56,378	4,192,507
1969	34,949	2,168,610
1970	65,411	3,890,565
1971	63,025	3,161,020
1972	65,299	3,505,991
1973	56,487	4,587,448
1974	64,129	9,544,063
1975	54,397	7,880,584

3.6.4 SELENIUM

Year	Kilograms	Value $ Can.
1961	74,753	1,071,200
1962	64,826	821,961
1963	43,137	461,235
1964	47,584	508,789
1965	55,872	597,399
1966	50,349	538,350
1967	61,144	653,780
1968	57,833	618,375
1969	38,102	480,480
1970	59,650	1,130,952
1971	58,060	1,163,520
1972	49,343	969,257
1973	43,069	867,843
1974	58,289	2,023,938
1975	48,852	1,971,987

3.6.5 TELLURIUM

Year	Kilograms	Value $ Can.
1961	3,451	39,043
1962	3,180	42,068
1963	3,495	50,082
1964	3,583	51,350
1965	4,225	60,548
1966	4,082	58,500
1967	2,948	42,250
1968	2,994	42,636
1969	2,545	36,241
1970	3,323	45,928
1971	3,674	49,086
1972	3,777	49,462
1973	6,961	93,150
1974	8,831	158,080
1975	6,934	144,606

3.6.6 COPPER

Year	Metric Tons	Value $ Can.
1961	163,458	104,703,240
1962	134,722	91,797,177
1963	121,504	84,168,123
1964	144,634	106,242,720
1965	157,827	130,494,150
1966	137,945	136,266,180
1967	158,908	166,386,770
1968	170,598	180,516,200
1969	127,326	144,031,070
1970	192,649	245,982,650
1971	187,983	218,294,820
1972	176,582	197,865,100
1973	179,808	252,601,220
1974	195,856	334,439,120
1975	167,817	235,663,150

Statistics Canada
Catalogue 41-214

3.6.7 COBALT

Year	Metric Tons	Value $ Can.
1961	1,444	4,751,543
1962	1,579	6,345,205
1963	1,372	6,122,169
1964	1,444	5,990,973
1965	1,655	7,529,143
1966	1,593	7,107,963
1967	1,635	7,352,433
1968	1,828	8,687,652
1969	1,477	6,851,046
1970	2,069	10,207,366
1971	1,961	9,249,564
1972	1,520	8,320,722
1973	1,517	8,899,200
1974	1,564	10,113,909
1975	1,354	12,547,883
1976	1,373	11,769,000

3.6.8

Year	Total Value Produced*	Copper Value	%	Other*	%
1966	523,380,000	136,266,000	(26.0)	49,500,000	9.5
1967	638,086,000	166,387,000	(26.1)	53,500,000	8.4
1968	707,981,000	180,516,000	25.5	62,200,000	8.8
1969	649,207,000	144,031,000	22.2	42,000,000	6.5
1970	1,034,677,000	245,983,000	23.8	60,900,000	5.9
1971	855,146,000	218,294,000	24.7	55,700,000	6.3
1972	860,698,000	197,865,000	23.0	50,900,000	5.9
1973	1,161,875,000	252,601,000	21.7	61,600,000	5.3
1974	1,478,825,000	334,434,000	22.6	91,400,000	6.2
1975	1,213,796,000	235,660,000	19.4	87,300,000	7.2
1976	N.A.	N.A.		N.A.	

* Excludes iron ore, sulphur and urea.
Iron shipments are about 650,000 tons in recent years, equal to 16 to $17,000,000/year.

3.7 Manitoba, Saskatchewan and British Columbia — mine production

a) MANITOBA ORE AND CONCENTRATE PRODUCTION

At the present time, virtually all the nickel from Manitoba is mined by INCO Limited which has five major mining properties near the geographical centre of that Province. The Thompson Mine was brought into production early in 1961 and production capacity has attained the level of approximately 8,000 tons of ore per day. This was achieved by the development of three shafts, the deepest of which, (No. 1 production shaft) reaches a depth of 4,430 feet. This and four other properties are located near Thompson, Manitoba, but Thompson and Pipe are the only operating mines at the present time.

The Birchtree Mine is located close to the Thompson Mine, and was discovered in 1964. Production commenced early in 1969, and reached a peak rate of 4,000 tons per day. Since then the production rate has been reduced at least twice, and it was announced in October, 1977 that it will be placed on a standby basis, concurrent with laying off 650 workers.

Two shafts have been sunk at the Soab Mine which is located west of the Grass River, some forty miles south west of Thompson. In 1971 the production rate was 4,000 tons per day, but this was suspended in September when the mine was placed on a standby basis, owing to the deteriorating condition of nickel markets.

The Pipe property is located at Pipe Lake, about 20 miles south of Thompson. This property was initially developed by an open pit (which required dredging a lake) and 2 shafts. The No. 1 shaft has been completed to a depth of 1,785 feet, opening one level at approximately 1,500 feet, and the No. 2 shaft was sunk to 3,061 feet. Production at the scheduled rate of 16,000 tons per day commenced in 1971, but was reduced at the open pit in October 1971 and suspended at the number one shaft by December 1, 1971. However, underground exploration continued at least through 1975.

At Moak Lake underground development work has been carried out on several levels established from an exploration shaft sunk to 1,325 feet.

Since the development of the Thompson, Manitoba ore deposits INCO has been able to work with a much higher average nickel grade material at the concentrator. Consider the fact that in 1976, INCO's Canadian operations averaged 1.41% nickel; although a breakdown between Ontario and Manitoba is not available, one can surmise that the higher weighting of grade still results from the Manitoba operations. This can be deduced from INCO's 1971 prospectus (for a $150 million bond issue) where it is stated "in 1970 INCO mined a total of 23,811,000 tons of ore in Ontario, with a nickel content of .99% and a copper content of .84% and a total of 386,700 tons of ore in Manitoba, with a nickel content of 2.18%, and a copper content of 0.14%".

The Thompson deposits contain nickel sulphide ores, the same general type as those of the Sudbury district. They are, however, relatively lower in copper grade compared to Sudbury, and also have lower contents of cobalt, palladium, platinum, gold and silver. On February 1, 1961 the completely new community of Thompson had a population of 1300 men, women and children, and the population grew to about 3,500 by year end. By the end of 1962 the population had increased to approximately 6,500 permanent residents. The Soab and Birchtree Mines are connected by a 45 mile railway to the town of Thompson. The Birchtree mine came into production in early 1969, an additional three miles on the railway provided transportation from Pipe to Thompson.

Early in 1959 a decision was reached that the output of the Thompson mine would be refined locally. Production of electrolytic nickel began in early 1961, and at that time Thompson was the world's second largest nickel producing centre (after Sudbury). This represented the culmination of 15 years of exploration and development, including 50 months of planning and a capital cost of $185 million.

Other past and present operations in Manitoba include the Manibridge and the Bowden Lake Nickel Mines of Falconbridge Nickel and the Lynn Lake Mine of Sherritt Gordon Mines Ltd.

The Manibridge property of Falconbridge Nickel Mines is located in the northern Manitoba nickel belt. This was a small high grade deposit estimated initially at 1.4 million tons of reserves containing 2.55% nickel and 0.27% copper per ton. The property was brought into production in June 1971 at an estimated cost of $14 million and a mill capacity of 1,000 tons per day. Full output of 1,000 tons per day was expected to be achieved by mid-1972, but it eventually became apparent that continued ground control problems and the shortage of skilled labour would restrict the output to two thirds capacity. Ore production climbed from a low of 123,380 tons in 1973 to a high of 208,000 tons in 1976. The mine closed in the middle of 1977 due to exhaustion of ore reserves.

Falconbridge earned a 67% interest in Bowden Lake Mines by carrying out extensive exploration of the latter's nickel property in the Wabowden nickel area of northern Manitoba. Diamond drilling indicated tonnage on the Bucko Lake property estimated at 30 million tons grading .78% nickel. Assessment of the deposits was completed in 1973 and it was decided to defer further development owing to the low grade encountered.

After INCO, Sherritt Gordon Mines Ltd. operated the next largest nickel mine in Manitoba. This was known as the Lynn Lake Mine which came into production in 1954 achieving a maximum production in 1965 of 1.237 million tons of ore per year. By 1975 production had declined to 319,000 tons of ore and the mine closed in mid-1976. The average grade mined during 1976 was.97% nickel and .42% copper.

TABLE 3.7

MANITOBA ORE AND CONCENTRATE PRODUCTION

Year	Nickel Content (metric tons)	Value (Canadian Dollars)
1946-53	no production	
1954	2,966	3,617,096
1955	12,490	17,376,749
1956	9,924	14,105,406
1957	9,103	14,725,014
1958	8,870	13,328,056
1959	9,198	13,523,225
1960	8,219	12,400,485
1961	29,918	50,039,745
1962	55,776	102,586,080
1963	57,684	106,822,890
1964	56,577	104,772,910
1965	57,346	106,196,350
1966	52,447	98,447,063
1967	49,636	103,585,380
1968	52,548	117,601,240
1969	58,895	147,612,640
1970	71,779	214,823,340
1971	69,463	210,562,710
1972	60,081	188,084,016
1973	67,661	228,222,210
1974	59,332	222,232,448
1975	63,854 (preliminary)	293,296,000
1976	n.a.	n.a.

Source: Spoerri, A. E., 1976, Mineral Production of Canada by Province, 1931-1975, Information System, Energy, Mines and Resources, Canada.

b) SASKATCHEWAN

Uranerz project, Key Lake area

Deposit, Gaertner, 500,000 metric tons, contains 4.54 per cent U308 and 3.84 per cent nickel or approximately 49.4 million pounds U308 and 41.8 million pounds of nickel.

Limited data. Deilman indicates 12 million pounds of U308, 8 million pounds of nickel.

The amount of nickel that is recoverable may be much less.

c) BRITISH COLUMBIA

There is nickeliferous pyrrhotite associated with copper in the gabbro copper mines on Vancouver Island.

3.8 Policy Issues and Current Problems

The major items in this category are further processing, idle refining capacity and the Sudbury and Port Colborne layoffs and are discussed in the next few sections.

3.9 Canadian Further Processing Facilities and Their History

The policy of the Government of Ontario has been that minerals produced in the Province shall be processed in Canada to as advanced a degree as is reasonably possible. An advanced degree of processing increased the income to Canada from minerals exported and results in more employment for Canadians.

This policy, followed for over 60 years, has had some success.

Ontario's objective of processing its mined output to the prime metal or saleable form in Canada, (not necessarily Ontario), has been largely achieved in the case of copper, and to a much lesser extent in the case of nickel. Quebec's smelter-refinery facilities have been a major beneficiary of this Ontario policy.

However, after 75 years, *no Canadian primary refinery as yet exists for platinum group metals,* which are valuable co-products of nickel mining.

Further processing policy is implemented by two methods. Section 113 of The Ontario Mining Act provides a legal basis for the Government to insist on processing to the metal stage in Canada. The Ontario Mining Tax Act provides for tax incentives to encourage it.

3.10 Royal Ontario Nickel Commission Report, 1917

An inquiry into the resources, industries and capacities of the Province of Ontario in connection with nickel and its ores commenced on the 9th of September, 1915. The investigations took the form of literature search plus inspection of mines and facilities in Ontario, New Caledonia and Tasmania as well as in Cuba and Norway. The entire commission spent two months visiting plants manufacturing "nickel steel" at various locations in the United Kingdon. Inco's facilities at Bayonne, New Jersey were also visited. Subsequently a report was submitted to the Lieutenant-Governor of Ontario on March 19, 1917.

Two questions were uppermost in the numerous discussions concerning Ontario's nickel industry which, at that point, had been in existence for approximately 25 years. These questions were:

1) Can nickel be economically refined in Ontario?

and

2) Are Ontario nickel deposits of such a character that this province can compete successfully as a nickel producer with any other country?

The 1917 Royal Commission's conclusions were:

1) The nickel ore deposits of Ontario are much more extensive and offer better facilities for the production of nickel at a lower cost than do those of *any* other country. Nickel bearing ores occur in many parts of the world but the great extent of deposits in this province, the richness in uniformity in metal content and the success of the industry points strongly to the conclusion that Ontario nickel has little to fear from competition.

2) Any processes now in use for refining nickel could be successfully worked in Ontario. Conditions and facilities are at least as good in this province as in any part of Canada.

3) Electrolysis would be the most satisfactory method of refining.

4) Refining nickel in Ontario would lead to the introduction of new industries into the province.

5) The methods employed at the Ontario plants of the two operating nickel companies (Inco and Mond) are modern and efficient.

6) The present system of mining taxation in Ontario is just and equitable. It is in the public interest and is the best system for this province. Any question of change is one of taxation rate rather than of principle.

The report goes on to say that the commissioners are gratified at the assured prospect of the erection in Ontario of two large plants for the refining of nickel, one by International Nickel Company of Canada Limited at Port Colborne and the other by British American Nickel Corporation Limited, probably at Sudbury, if a supply of electric power can be obtained. It was also noted that when the commissioners began their work, it was asserted by the interested companies that nickel could not be economically refined in Ontario. The question was also raised regarding a market for nickel ore or matte produced by small operations (since minor amounts of ore was being mined at that time, except by the large companies). *Only the British American Corporation expressed a desire to further discuss this topic of custom smelting and refining with the government.*

The suggestion was also made that government ownership would solve many of the questions which have been raised in connection with the nickel deposits. However, it was estimated that to expropriate Sudbury nickel operations it would probably cost not less than $100 million. At that time, this sum was approximately *equal to the total paid up capital stock of all the chartered banks in Canada.* The problems of risk were also mentioned as well as the level of technical knowledge needed for running such plants, as obstacles to the "public ownership solution". It was further stated that nickel is *"not a necessity of life nor article of universal consumption or use and the nickel business is in no way comparable to those connected with the operation of public utilities where government ownership may be beneficial or expedient"*. Therefore, they concluded that it does not seem to be any good reason why the people of Ontario should be asked to *adventure* so large a sum of money as would be required for the purchase of these nickel facilities.

Under the question of competition, it was stated that it would be futile to try to shut off the supply of nickel from almost any of the great nations. Nearly every important country has supplies of nickel ore which can be worked if demand is great enough (thus ensuring a high price). At that time they estimated that the proven plus possible ore supply would exceed 150 million tons, at Sudbury.

There was a considerable emphasis put on the type of refining process which should be used for Ontario nickel. At that time there were three known processes. These are: the Orford process which was employed for the treatment of the matte produced by the Canadian Copper Company; the Mond process; and electrolytic methods. For all processes, the production of a nickel matte is essential. Matte is made by substantially the same method for all three of these processes.

The International Nickel Company, until near the end of the commission's study, contended on commercial grounds that the Orford process could not be profitably operated in the province. These contentions were largely based on comparative cost as between New Jersey and Copper Cliff. It was pointed out, though, that by the time the commission's report was prepared the company had changed their mind regarding the cost on the north shore of Lake Erie, i.e. Port Colborne versus New Jersey. The Mond Nickel Company alleged that by reason of the greater expense due to higher wages, increased cost of fuel and chemicals and higher freight charges, refining in Ontario would make a material addition to the cost of their products, namely refined nickel and copper sulphate. Mond supplied the commission with figures in support of their view, developing a special argument based upon the necessity of quick delivery for copper sulphate which is marketed in the vine growing countries of the Mediterranean, and is required only during a limited season of the year for destroying mildew on vines and potato blight. There was, however, nothing to prevent the Hybinette process being operated as cheaply and as efficiently in Ontario as elsewhere. The cost at Sudbury was estimated to be less than it had been in Norway owing to the larger scale of operation in Ontario.

At about the time mining began in New Caledonia in 1875, the price of nickel, according to a report made by the government of France, amounted to about $1.58 per pound (1917 dollars). Owing to Canadian competition it fell to 2.4 francs per kilogram (.21¢ per pound) at the end of 1895.

As a result of this Royal Commission, the International Nickel Company expressed its intentions of establishing a refinery at a suitable place in the province. The report from the company contained the following facts: the refinery would be located at Port Colborne, Ontario at an approximate cost of $4 million and it would be ready and completed for operation in the autumn of 1917. Initial output levels were to be 15 million pounds of nickel per annum utilizing a work force of 400 men. The raw materials would include copper nickel matte supplied from northern Ontario plus numerous other materials such as bituminous coal, coke, fuel oil, etc. estimated annually at about 100,000 tons in total. There was an allowance for capacity increases of up to 4 times within a few years.

3.11 Section 113

A subsidiary company called the International Nickel Company of Canada Limited was incorporated under the Dominion Companies Act on the 25th day of July, 1916 with comprehensive powers to produce, manufacture, refine, smelt and deal in nickel, copper, iron, steel, manganese, cobalt, coal coke, platinum, palladium, and other minerals and mineral substances and other incidental objects. The Ontario Refining Works were to be operated by this new company and all assets and properties connected with them vested in it.

Subsequent to the Royal Ontario Nickel Commission Report, there was a change (April 12, 1917) in the Ontario Mining Act which introduced a section which is now known as Section 113. This section undoubtedly had much influence on International Nickel Company's decision to build their refinery, owing to the potential loss of mining rights if they did not prove their intention to process to a product "suitable for direct use in the arts".

From the time of the passage of the original version of Section 113 in 1917, it has been recognized that passage of a law does not automatically make economic sense out of economic nonsense and that in some cases 100% processing in Canada is not a sensible objective for technical and other reasons. Provisio

was therefore made for exemptions by Order in Council. Exemptions currently existing were obtained for one or more of the following reasons:

i) Where no further processing facilities exist in Canada and the benefits obtainable appear to be too low, (in relation to costs), to justify construction;

ii) Where inadequate further processing capacity exists in Canada and funds for construction are not available at this time;

iii) Where inadequate further processing capacity exists in Canada and ore reserves are insufficient to justify construction;

iv) Where quantities of semi-processed material exported are too small to justify construction of a Canadian processing plant;

v) Where the semi-processed material is not acceptable to Canadian further processors due to undesirable impurities which interfere with refining or other metals. Quantities involved are insufficient to justify modifications to Canadian plants;

vi) Where the semi-processed material is not acceptable to Canadian further processors due to impurities causing environmental pollution. Quantities involved are insufficient to justify modifications to Canadian plants to meet government requirements;

vii) Where foreign customers are unwilling to accept fully processed material and are able to obtain their requirements from other sources if denied from Ontario supplies;

viii) Where export of semi-processed material is necessary until new Canadian plant construction, now in progress, is completed.

Section 113 serves as a useful monitoring device and enables the Ontario Government to review the situation regularly and to ensure that as much processing as is economically feasible is carried out in Canada. The tax incentives under The Mining Tax Act are more positive and therefore more effective in that they increase the economic advantages for industry of building processing plants in this country. Additional incentives are offered for construction in Canada and especially Northern Ontario. These incentives and particularly the processing allowances increased in 1974, have been instrumental in inducing major new investments in Northern Ontario, such as *Inco's* strip mill and the *Texasgulf* copper refinery.

3.12 Incentives in Taxation of Minerals in Ontario for Further Processing

The Ontario Mining Tax Act, dating from 1907, is aimed at securing for the people of Ontario a return from the extraction of its mineral resources. UNDER THE CANADIAN CONSTITUTION, THE NATURAL RESOURCES BELONG TO THE PROVINCES. THE TAX IS A PRICE PAID TO THE PEOPLE OF ONTARIO FOR THE ONE-TIME REMOVAL OF THE RESOURCE FROM THE GROUND.

To understand the taxation of the mining industry in Ontario we must first examine the nature of the tax. The Ontario Mining Tax is a tax on profits derived solely from a mining operation. It is not a corporation income tax nor is it a tax on profits from various mine output processing operations such as concentrating, smelting and refining. It is a much older tax than any income tax in North America.

The Ontario Mining Tax on the profits of a mine has the advantage that it takes into account expenses of extracting the ore and the rise and fall of international commodity prices and, consequently, it does not discourage the mining of low-grade ore. (A royalty system, on the other hand, tends to encourage the mining of only the higher grades of ore.) The graduated mining tax rates captures a fair share of an increase in profits. This secures a large share of gains without imposing an unfair burden of taxation when world metals prices and profits decline.

The low initial rate of the graduated tax is of assistance to the smaller mining companies, whose operations often provide the only major source of employment in isolated northern communities.

Other incentives in the Mining Tax Act are:

1) it allows the disaggregation of major new mining investments for the purpose of calculating the mining tax. In effect, this allows new mining investment to earn its way up the marginal rate structure. This is to encourage new mining projects and provides equal tax treatment to all companies in respect of future mining operations in Ontario.

2) the depreciation allowance of 30 per cent on new mining assets acquired after April 9, 1974 is a further incentive to encourage the expansion and modernization of Ontario mining operations.

3) to increase exploration and development activities in the province, 100 per cent of exploration and pre-production expenses is allowable as a deduction in computing the mining tax.

4) to encourage the construction of mineral processing facilities in Ontario, particularly Northern Ontario, incentives are provided by way of annual processing allowances which range up to 35 per cent a year of original capital cost for an operator who processes to a semi-fabricated state. THIS GENEROUS PROVISION HAS MADE ONTARIO FAMOUS IN THE WORLD OF MINERAL TAXATION.

These and other features strengthen the base of Ontario's mining industry, encourage new investment, exploration and expansion and provide increased economic benefits to Northern Ontario. The purpose of the incentive system is to encourage the construction of more processing facilities in Northern Ontario which will add value to Ontario's mineral output to the benefit of Ontario as well as Canada as a whole. The by-product of this activity is the creation of more jobs than would otherwise exist and thus effect the growth and stabilization of our Northern communities.

The Ontario mining industry is pressing for changes in the Ontario mining tax in the short term and the Ontario Minister of Natural Resources, the Honourable Frank S. Miller, has also promised a fundamental long-term review of the taxation burden of Ontario mines.

LONG TERM STABILITY IN MINERAL TAXATION LEGISLATION — BOTH FEDERAL AND PROVINCIAL — IS REQUIRED TO FACILITATE THE PLANNING AND FINANCING OF EXPLORATION AND NEW MINING PROJECTS.

The mining industry in Canada has lost its long-standing Federal incentives for mineral exploration and exploitation. In addition, the Federal government did not maintain a stable tax environment after the tax reform in 1972. Budgetary changes in 1974 and 1975 led to a high level of uncertainty in the Canadian mining industry.

ONTARIO MINING TAX REVENUE

(as per published Ontario Government Public Accounts, Statement of Revenue)

1977/78	$ 23,000,000 est.
1976/77	41,041,961
1975/76	62,438,191
1974/75	152,105,039
1973/74	46,309,367
1972/73	16,344,255
1971/72	13,322,701
1970/71	24,731,492
1969/70	23,890,238
1968/69	19,615,792
1967/68	16,105,638
1966/67	10,640,398
1965/66	14,889,068

CANADIAN FEDERAL INCOME TAX

(including income tax on non-operating revenue)

1975	$77,043,000
1974	78,824,000
1973	15,276,000
1972	4,321,000
1971	25,320,000
1970	13,130,000
1969	20,026,000
1968	30,789,000

Specified taxes paid by companies engaged in nickel-copper operations. Includes Smelting and Refining operations and other related activities associated with Canadian Operations of nickel-copper mines.

Ref: Catalogue 26-211 Nickel-Copper Mines Statistics Canada.

3.13 Idle Nickel Refining Capacity in Canada

In Canada there are two plants with idle nickel refining capacity no longer treating nickel material from Canadian Mines:

1) Sherritt Gordon's nickel refinery at Fort Saskatchewan, Alberta — because Sherritt's only Canadian nickel mine has been shut down. The refinery does treat material from Australia etc. on a custom basis. Precious metals are not recovered in this plant however.

2) Part of INCO's electrolytic nickel capacity at Port Colborne, Ontario was shut down in 1977. The process is probably less economic than the new carbonyl refining process at Copper Cliff, Ontario. The electrolytic nickel cathodes, (Class I nickel), formerly produced at Port Colborne, are more difficult to sell.

Mine Capacity (nickel content)		Unused Nickel Refining Capacity located in Canada
	(metric tons per annum)	
Falconbridge (all goes to Norway)	43,000 capacity.	Nil, because company has no refinery in Canada.
INCO	170,000	32,000 estimated (located at Port Colborne, Ontario)
Sherritt nickel mine in Canada closed down		18,000 estimated (partly used for nickel strip and occasional custom refining) (located in Alberta)
	Total:	50,000 estimated

Summary (metric tons of nickel)

Unrefined Nickel Exported from Canada (at full capacity)		Unused Nickel Refining Capacity in Canada (estimated)	
Falconbridge	43,000	INCO	32,000
		Sherritt	18,000
			50,000

3.14 Layoffs in Canadian Nickel Operations

MARKET DECLINE AND CUT-BACKS IN OUTPUT

During the 1971-72 period of very low demand for nickel, almost the whole burden of the market decline fell upon INCO of Canada. Although the Company has never really been the same since — at least as far as marketing impact is concerned — the collective burden of the current downturn is now spread around with greater equity.

The 1976/77 nickel price war may have damaged some newcomer nickel mines more than INCO. The new nickel producers in Australia, the Philippines, Africa, U.S.A. and Comecon were selling well below INCO's "producer" price, which was abandoned in mid-1977. This means that INCO can now fight for sales on the same terms as its competitors. For example, one of the newcomer mines, the Dominican Republic nickel operation, (Falconbridge), which opened up in late 1971, *cut back production* severely in both 1975 and 1976. The large new Vuonos nickel mine in Finland which came on stream in 1972, *stopped producing* in mid-1977. Western Mining, *Australia*, cut output by 10 per cent and laid off 600 workers in the fall of 1977. Poseidon Nickel, Australia, went into receivership late in 1976. The new Queensland, Australia laterite operation of Greenvale is in financial difficulties.

The French SLN nickel mining company in new Caledonia *cut back output* in 1976 and further reduced output to about 70 per cent of capacity early in 1977. South Africa's nickel output *fell* about 6 per cent in 1975 and 1976, compared with 1974.

The Amax Nickel division of Amax Inc., U.S.A. said that to avoid excessive inventories, production at its Port Nickel refinery in Louisiana will not be increased to capacity as quickly as originally anticipated. Output is approximately 23,000 metric tons of nickel in 1977, about 25 per cent above the 1976 level. For the first half of 1978 Amax will maintain production at a rate no greater than that of the second half of 1977 and in mid-year 1978 will again review the market situation to establish operating levels for the balance of 1978.

The President of INCO Ltd. said in October, 1977 that:

1) INCO's 1977 Canadian nickel production would be less than in 1976.

2) INCO will produce *more than* 145,000 metric tons of nickel in 1977.

Operations will be suspended at two mines, *Copper Cliff North* in Sudbury, Ontario and Birchtree near Thompson. Production from the Stobie portion of the Frood-Stobie, Ontario mine will be reduced while production from *No. 3 mine* in the *Creighton* complex, Ontario *will cease*.

Production from the *Crean Hill mine*, Ontario will be gradually reduced until operations are *suspended in mid-1978*. The *Victoria mine* in Sudbury, Ontario which INCO said is depleted, will be *closed permanently*, but the other mines will be maintained on a standby basis until market conditions permit re-opening.

INCO said the production curtailment will also involve a *summer shutdown* of Ontario division operations *for four weeks*, starting July 17, 1978. About 85 per cent of the division's employees will take paid vacations for the entire shutdown period.

EVEN FURTHER PRODUCTION CUTBACKS MAY PROVE NECESSARY IN THE FIRST HALF OF 1978, INCO SAID.

More mine output cuts may be announced by INCO during 1978 to get the inventory of finished nickel into better balance.

INCO's Ontario labour contract expires in mid-1978.

Falconbridge is doing much the same in the Sudbury area in early 1978. Falconbridge had *reduced output* in Canada in 1975 and 1976 and closed all its Ontario mines for one month and certain other shorter periods in late 1977.

INCO Europe Ltd. is reducing the work force at its Welsh refinery at Clydach by about 9 per cent, so that 1978 metal production there will be about 35 per cent below the level planned for 1977.

3.15 Select Committee of the Ontario Legislature

An 18-member Select Committee of the Ontario Legislature is to enquire of senior officials of INCO Ltd. and its employees as to the factors and circumstances leading to the decision to announce layoffs at the Sudbury and Port Colborne operations. The intention was to report by the end of 1977, or early 1978.

3.16 Ontario Cabinet Committee

A Cabinet Committee has been appointed, under the chairmanship of the Honourable Frank S. Miller, Minister of Natural Resources, to look into the future of Northern Ontario communities, many of which are dependent on mines.

3.17 Importance of the Nickel Industry to Municipal Centres

There are two Canadian municipal centres which depend largely upon the fortunes of the nickel industry for survival: Sudbury and the surrounding area in Ontario; and Thompson, Manitoba.

Sudbury began as a rudimentary frontier community in the latter half of the 19th century, primarily as a result of the C.P. Railway which owned and first surveyed the town site in 1887.

The town continued to grow and became incorporated in 1893 with a population of 1,000. At that point Sudbury was without sidewalks and sewage ran in the gutters. In fact, even drinking water which is now so plentiful in any part of Canada was obtained from a spring that bubbled out of a gravel pit, and householders paid a water peddler to keep their barrels filled.

In 1887 a system of electric light, water works and sewage disposal was installed. Another forward step was achieved in 1902 when the Bell Telephone Company wired Sudbury and Copper Cliff for their first telephones. This was a very significant contribution to the community since at that time even areas adjacent to Toronto did not have such utilities in every household.

In 1900, the C.P.R. had completed its line from Sudbury to Sault Ste. Marie, thus providing connections with Chicago and the western United States. By 1908, rail connections were established from Toronto to Capreol, Ontario and from Capreol to Sudbury. (This system subsequently carried the famous Jules Garnier in his initial examination of Sudbury ores). Then in 1912 Sudbury was linked to North Bay by a highway, thus providing alternate access.

The fortunes of Inco and its founders blossomed during the 1920's during which time the population of Sudbury rapidly increased to about 20,000 people. The City was incorporated in 1930, thus establishing it as a judicial and political centre of the entire district as well as being the nucleus of commerce.

Owing to the city's dependence upon one industry, the depression of the 1930's had a devastating effect on Sudbury. This eventually led to a default on municipal debentures, and the city went into receivership for a few years.

Much of the lack of vegetation and the accompanying bleak environment of the Sudbury district is blamed upon the nickel industry. For instance, it was common practice to roast sulphide ores of the Sudbury district in an open yard where most of the sulphur was removed by its own combustion. Heaps of ore was placed on a foundation of wood which was set on fire, thus igniting the sulphur and it was allowed to burn for as long as several months until about 90% of the sulphur was consumed. From the roast yard, the ore was sent to a blast furnace for production of "matte". This process of roasting the ores, of course, consumed a large quantity of timber from local sources. In addition, the open roasting of sulphur of course, destroyed the vegetation in the surrounding area. However, it should also be pointed out that the south west portion of the Sudbury basin, like many parts of the Canadian shield, has a particularly thin layer of soil and therefore large trees can be sparsely dispersed.

Because of this thin soil cover, special problems are presented with water pipes which are normally buried to prevent freezing in winter, and the need to blast out basements, foundations, streets, excavations for water mains and sewers. Along with the inherent dangers of freezing water pipes is the extra winter fire hazard and the need for such emergency water sources.

In contrast to this outer rim of the Sudbury basin is the flat plain within the basin which contains a few low hills and a soil cover sufficient to support farms with dairy cattle. East of the basin the overburden is very thick and familar out-crops and ridges are not found.

Sudbury acts as the focal point for all other communities in the district. These include the town of Falconbridge and Lively, Creighton, Copper Cliff, Coniston and several other smaller centres. In 1950, population had grown to 47,054. Paradoxically it became known as one of the most congested towns in Ontario with about 17.1 persons per acre.

As of 1951, Sudbury had some 25 industries largely of the wholesale or supply type agency rather than manufacturing concerns, whereas Kitchener, a typical Southern Ontario city with a slightly smaller population, had 150 industries.

The Sudbury region has a population of about 200,000 people of which 24% of the labour force is employed in the mining industry. Mining is the highest individual employment source for the region and this 24% compares with 5.4% and 8.3% for the Province and Canada, respectively. Thirteen percent of the labour force in the region is employed in manufacturing while smelting and refining share 6.9%, leaving only 6% for secondary manufacturing employment. By comparison, manufacturing employment in Ontario and Canada are 24.5 and 19.8% respectively. The ratio of service employment to total labour force increased from 32.9% in 1951 to 40% in 1971 with the major increases occurring in community, business, and personal service industries.

It is apparent then that the city of Sudbury is still not able to significantly alleviate its dependence upon the fortunes of the nickel industry in the 84 years since it was first incorporated as a town. One positive aspect of this dependence however, is the fact that the people of Sudbury have become among the most highly paid in the country. For instance, over 46% of the Sudbury wage earners had annual incomes between $8,000 and $15,000 compared with 23.4% and 20.8% for Ontario and Canada. Further, the highest income group ($15,000 and over) constitute 5.6% of the region's population against 3.6% and 3% for Ontario and Canada.

It has been suggested that various types of manufacturing and metals consuming plants be located in the Sudbury area as a way of alleviating the unemployment problem. One suggestion is the establishment of a high nickel rolling mill in Sudbury. However, these are generally located close to major markets in order to serve the jet engine manufacturers. Unfortunately, Canada does not have an industry that will consume enough product to justify such a plant. It is also a fact of life that major consuming countries encourage local facilities because the high nickel alloys are considered strategic to defence production.

Tariffs on imports reflect this attitude, and U.S. law, for example, forbids the purchase of certain items from foreign sources for defence purposes, all of which mitigates against the establishment of significant production in the Sudbury area. Another suggestion is the establishment of a stainless steel processing and manufacturing plant in the region. It should be pointed out, however, that Canada is reasonably self-sufficient with respect to the production of stainless steel products. This is provided by Atlas Steels in Ontario and Quebec and Crucible Steel in Quebec. There is also an over-capacity of stainless steel in the world at present time and until recently only one new stainless steel plate mill had been added in the U.S. in the past eight years. In essence then it appears very unlikely that it would be economic to locate a stainless steel plant in Sudbury.

While it is possible for some light manufacturing facilities to be located in the region, for example, a battery plant (candidate location for E.S.B.) the region must in the long run be faced with an almost total dependence upon the industry.

The first home was built in Thompson, Manitoba in 1958. Inco had set up an exploration camp at Moak Lake 15 or 20 miles distant from the town site of Thompson and the future of the new town of Thompson was given some direction by the company engineers who insisted that no temporary buildings or dwellings of any kind, including tents, would be allowed on the town site. The rationale for this was the fact that temporary buildings have the habit of becoming permanent. On February 1961 the new community had a population of 1300 and in two short years it increased to 6500 permanent residents.

The latitude of Thompson, Manitoba is 55 degrees 41 minutes north. This latitude cuts through North America at Labrador, James Bay and the Aleutian Islands. As a result, the climate is extreme, including very cold winters and short, hot summers.

Thompson is located in the Local Government District of Mystery Lake. At the request of Inco, and subject to the approval of the Provincial Government, the Metropolitan Town Planning Commission of Greater Winnipeg laid out the town site. Facilities were provided (streets, sidewalks, electricity, sanitary and separate storm sewers, sewage treatment plants, telephone, water mains, fire protection, police schools, medical care including hospital, recreation facilities, municipal offices and assembly hall, bridges, etc.) and in part, the company paid the cost of building them. Under the contract with provincial government, certain facilities provided by the company became the property of the town. This included facilities such as sidewalks, roads, assembly hall, municipal offices, fire stations, sewers, water mains and schools. Electricity is supplied by the Manitoba Hydro Electric Board in the power plant on the Nelson River at Kelsey. While Inco is the prime customer in the area, there is a surplus of power for other uses. Water is piped down from the upper Burntwood River.

In Ontario most of the nickel communities are self-governing municipal corporations and the voters are company employees, but not exclusively. Often those who are elected to manage the town affairs are employees, but again this is not always the case. In Manitoba and under the terms of the Local Government District Act the government appointed administrator managed the affairs of Thompson from 1957 prior to the establishment of an elected municipal government, in 1967. Thompson officially became a city in 1970.

3.18 The Canadian Nickel "Pipeline" and Inventories —Mine, Mill and Refinery

The nickel pipeline consists of ore reserves (covered in Chapter 9) ore mined above and below ground, mill concentrates not further processed, nickel in matte, and saleable nickel products ready for shipment to market including nickel in matte, nickel oxides, cathode nickel, pellets and various nickel products for use in foundries and steel mills, as well as nickel salts sold to electroplater's supplies distributors.

The table exhibits short tons Canadian ore mined and milled; concentrate produced; total nickel produced from Canadian ores; imports of refined nickel; exports and nickel consumed in Canada.

Ore -

There is little if any change in ore inventory from year to year. It usually ranges from a maximum of plus or minus 2.0% of ore produced, but usually less than 200,000 short tons. The average ore inventory in the pipeline is estimated to be about 1 week's supply including ore underground mined but not hoisted, and ore in surge bins above ground. Since 1960, nickel produced in Canada as a percentage of ore mined ranged from a high of 1.29% in 1962 to a low of 0.85% in 1971. During 1970-1971 close to 34 million tons of ore was mined each year indicating the drive to replenish inventories after the prolonged strikes in 1969. Also new mills were no doubt experiencing start-up problems resulting in lower recoveries of nickel.

Mill Concentrates

Concentrate inventory and in process is estimated to be about one week of consumption of concentrate in the smelters in an average year. Concentrate produced averaged 22.0% to 26.0% of total ore milled each year from 1960 to 1967. From 1968 to the present, concentrate produced has been about 15.0% of ore milled. Concentrate produced decreased 8.2% in 1972 vs 1970 and a further 9.5%, 1975 vs 1972 or a total reduction of 26.1% 1975 vs 1970. It seems obvious that new mills have yielded better nickel recoveries than in the past resulting in a marked decrease in concentrates produced whereas we see a dramatic increase in nickel produced as a percentage of concentrate produced, (e.g.) in 1967, 21.9% of concentrates were recovered from ore milled of which 4.8% was recovered as nickel from concentrates. In 1974, 14.1% of concentrates were recovered from ore milled and 7.6% nickel was recovered from concentrate produced. It is estimated there is another 30 million pounds of nickel (about 3 weeks inventory) in process in the matte processing and Canadian refineries.

Nickel Product Inventory

During the period 1956-1975, inventory changes ranged from as much as a reduction of about 12% to an increase of 10% but generally any imbalance was rectified in the following 2 year period. Total change in inventory was an increase of saleable nickel products of about 85,000 metric tons of which 57% occurred in 1974 and 1975. Prior to 1974 the total inventory increase amounts to about 13% of a peak year's shipments, (i.e.) less than 2 months shipments.

Including imports of nickel from Falconbridge's Norway refinery, inventory in Canada increased 50,000 metric tons while concentrate produced was dropping dramatically (1970-1975). The increase in inventory of unsaleable nickel products in the past 20 months (1976-1977 August) is another 72,667 metric tons for a total increase of 122,472 metric tons from December 1969. Inventory in December 1969 was quite low because of the prolonged strike and probably 4-6 weeks shipments.

Thus the increased inventory of Canadian nickel in Canada is about 9 months of 1976 shipments or 94% of Canadian shipments in 8 months of 1977.

In 1974, Canadian nickel production was about equal to shipments, 1975 production was 109% of shipments, 1976 production was 108.7% of shipments, 1977 eight months figures show production to be 130.5% of shipments.

Of course, the Canadian nickel pipeline includes nickel in Inco's U.K. refinery and Falconbridge's Norway refinery. It also includes finished nickel in their warehouses in Europe and the U.S.A. and to a small extent Japan. Over and above the finished nickel inventories in producers' warehouses, there are distributors of the producers with inventory also. It is not known how much finished Canadian nickel is in warehouses outside Canada, but it should be in the order of 50,000 metric tons.

According to Metallgesellshaft Metal Statistics, there was a buildup of 455 million pounds (206,400 metric tons) of refined nickel during 1975 and 1976 of which Inco, according to their recent statement, would probably (end-1976) hold 50%.

TABLE 3.18.1

CANADIAN NICKEL, PRODUCTION, EXPORTS AND CONSUMPTION

	1962	1965	1969	1970	1971	1972	1973	1974	1975	1976	1977 P
	metric tons										
Ore Mined	16,302,975	21,999,214	20,179,735	31,291,313	31,284,160	23,096,804	23,168,447	25,302,883	23,264,967		
Ore Smelted Directly	889,629	908,962	504,674	828,714	584,006	247,603	234,662	240,741	219,219		
Ore Milled	15,445,960	21,099,812	20,630,458	30,307,133	29,969,963	22,992,320	23,502,579	24,950,164	22,931,291		
Total Ore Processed	16,335,589	22,008,774	21,351,132	31,135,847	30,553,969	23,239,923	23,737,241	25,190,805	23,150,510	N.A.	N.A.
Inventory Change	(32,614)	(9,560)	(955,397)	155,466	730,191	(143,119)	(568,794)	112,078	114,457		
Concentrates Produced	N.A.	N.A.	3,295,179	4,663,688	4,542,095	3,811,442	3,431,321	3,523,423	3,445,050		
Imports	6,799	11,042	11,432	10,729	12,761	16,330	14,643	15,234	11,365	14,379	384
Total Nickel Produced	210,690	235,130	193,789	277,495	267,027	234,953	249,051	269,076	244,786	238,898	166,940
Total Nickel Available	217,489	246,172	205,221	288,224	279,788	251,283	263,694	284,310	256,151	253,277	167,324
Canadian Consumption	4,828	8,096	10,972	10,700	7,788	9,242	10,761	11,567	11,308	11,521	11,612
Exports — Nickel in Matte	70,226	74,687	69,833	87,689	105,685	104,146	91,069	85,241	84,392	72,756	51,470
Exports — Nickel in Oxide	10,093	37,155	26,317	39,822	38,787	33,261	59,711	51,119	38,527	47,954	25,624
Exports — Refined Nickel	110,417	122,650	94,569	138,986	113,834	108,976	120,668	119,383	90,821	87,713	39,465
Total	195,565	242,588	201,691	277,196	266,095	255,608	282,210	267,310	224,957	219,765	128,171
Inventory Change	21,924	3,584	3,530	11,028	13,693	(4,325)	(185,514)	17,000	31,194	33,512	39,153
Inventory Change as % of Nickel Available	10.1	1.5	1.7	3.8	4.9	(1.7)	(7.0)	6.0	12.2	13.2	23.4
Nickel Produced as % of Concentrate	5.3	4.9	5.9	6.0	5.9	6.2	7.3	7.6	7.1	N.A.	N.A.

Source: Canadian Mineral Year Books — Nickel-Copper Mines — Catalogue 26-211, Statistics Canada
Catalogue 26-003 Copper and Nickel Production, Statistics Canada
Catalogue 65-007 Imports by Commodities, Statistics Canada
Catalogue 65-004 Exports by Commodities, Statistics Canada
P — Preliminary, 8 months
N.A. — Not Available

3.19 Canadian Industry Financial Performance 1946-1976

The financial performance of three principal Canadian nickel producers is examined below over the time period 1946-1976. While one corporation, INCO Ltd. has been in existence for a much longer period of time, i.e. since the turn of the century, Falconbridge began producing in the mid 1930's and Sherritt Gordon in the mid 1950's.

In the tables given in Appendix A3 the salient financial statistics are depicted. It was attempted to make the definitions uniform, but where this is not possible, the data is presented as given in the individual companies' annual reports.

Starting with INCO Ltd., it should be noted that net profits increased by slightly under seven times in the 30-year period and operating costs increased by almost 20 times. Time does not permit a full treatment of inflation accounting, but it could be easily verified that the growth in profits, after making allowance for expansions in capacity, has not exceeded the western world's rate of consumer price inflation.

For example, looking at 1956 and 1974 i.e. the peak of two cyclical highs in mining corporation profits, it can be seen that INCO's profit increased from $96.3 million in 1956 to $306 million in 1974, whereas the profit per pound of total nickel and copper delivered only doubled during that time period from 17¢ per pound to 33¢ in 1974. In addition to the rapid escalation in labour rates one could also identify the equally rapid escalation in taxes. Therefore, in order to maintain this level of profits, it has been necessary for INCO to become more and more efficient. For instance, in 1967 the total metals business employees numbered 32,552 and they produced 774.4 million pounds of nickel and copper combined. This compares with 916.3 million pounds of nickel and copper in 1974, and virtually the same level of employees. There is, however, a limit to how long a company can reverse the trend of decreasing profits by looking for new methods to improve efficiency. Considering the cost of deep mining in the Sudbury basin, it would appear that this limit has long been passed.

ESB Incorporated became a subsidiary of INCO on August 1, 1974, following a tender offer of $41 per share. The cost of this acquisition, net of working capital acquired, was $104.65 million and as an indication of the success of this investment, ESB contributed $38.6 million to earnings before income and mining taxes in 1976. This is an interesting diversification for INCO since ESB is one of the world's major manufacturers of batteries, and operates 96 plants in 18 countries. Its products are marketed under such trademarks as "Exide", "Ray-O-Vac" and "Willard". Non-battery products include electric motors, medical-electronic devices, chemicals and plastics.

While profit per pound statistics have steadily increased with time, the same is not true for rate of return statistics, such as "return on total assets." This latter statistic is quoted directly from INCO's annual reports, and it is defined as profit divided by total current and fixed assets. This definition is not a common measure of return on investment. However, it is one presented by INCO Ltd., and, therefore, is likely to be useful for comparing that company with Falconbridge Nickel and Sherritt Gordon Mines. It can be seen that the peak rate of return on total assets of 16.8 percent was achieved in 1956 and this high level has yet to be attained in subsequent years. In fact the current level of approximately 5.4% in 1976 is close to the post World War II historical low which occurred in 1971. Indications are, however, that 1977 and 1978 will see even further declines in income relative to total assets.

Turning to Falconbridge Nickel Mines, similar statistics are presented in Appendix A3. These two mining companies are not directly comparable, owing to the greater concentration in the nickel industry by INCO, but it can be seen that similar trends in profitability have developed with this latter company. Whereas the growth in sales has been much more spectacular with Falconbridge amounting to almost a hundred times during the 30 year period, the growth in total profits has not been nearly so pronounced. Details of nickel deliveries are not available for the entire period, but it can be seen that generally Falconbridge's growth in nickel sales has been much more spectacular. This presumably results from the U.S. Defence contracts negotiated by Falconbridge. Nevertheless, comparing the peak years 1956 and 1974, it can be demonstrated that Falconbridge's profitability has not kept abreast of inflation. Similarly, return on total assets (defined as before) reached a peak in 1950, and as with INCO, this historical high has yet to be attained again during the entire 30 year period. In fact, in 1976 the return on total assets dipped to an all-time low of 2 percent compared with 14.4 percent in 1950.

While similar trends can be depicted in the financial performance of Sherritt Gordon Mines Ltd., this company started off as a nickel producer in Manitoba in the early 1950's, but by mid 1970's it had essentially become a copper-zinc producer. Therefore, the financial performance is not directly comparable with INCO. However, during the period under which Sherritt Gordon was strictly a nickel-copper producer, it is apparent that the profitability of INCO was much more consistent.

The principal reason for INCO's strength lies in the level of output, economy of scale and the relatively high grade that it has been able to maintain. This fact is clearly demonstrated in salient statistics in recent years. Here we are comparing INCO with its principal competitor, Falconbridge Nickel Mines. It can be seen that average nickel grade mined of INCO is marginally greater than that of Falconbridge, whereas its production level is almost six times higher. Therefore, operating costs per pound of nickel should naturally be proportionately lower. At the same time INCO's co-product copper grades are also considerably higher than that of Falconbridge. There is little question, therefore, that in a depressed market for both nickel and copper that INCO will maintain a much higher return on investment than Falconbridge. Further, unless metal markets soon improve, Falconbridge could experience serious financial difficulties.

SALIENT STATISTICS — recent years

	1972	1973	1974	1975	1976
Inco					
Ore production (million tons)	19.2	19.7	22.0	21.2	19.8
Average nickel grade (%)	1.33	1.41	1.39	1.40	1.41
Average copper grade (%)	0.91	0.98	0.97	0.92	0.97
Nickel deliveries (million lbs)	409.8	351.1	549.1	517.0	425.1
Falconbridge Nickel Mines					
Ore production (million tons)	4.364	4.429	4.521	3.230	3.219
Average nickel grade (%)	1.34	1.32	1.30	1.30	1.32
Average copper grade (%)	0.70	0.66	0.66	0.69	0.68
Nickel deliveries (million lbs)	80.2	61.5	89.5	99.4	89.7

Source: 10K Reports Inco and Falconbridge.

It is apparent from the above statistics as well as a perusal of financial information prior to 1946, that the "golden" years of Canadian nickel mining were from 1932 to 1956. It is most unlikely that such an uninterrupted span of abnormal return on investment will occur in the near future.

3.20 Nickel Industry Capital & Exploration Expenditures

The three largest Canadian nickel companies have invested appreciable amounts of capital outside of Canada since the 1930's. In addition, there are numerous other Canadian organizations which have made extensive investments in foreign nickel related facilities. Examples of this are the Canadian Government via agencies such as the Canadian International Development Agency (CIDA), and the Export Development Corporation. Other examples are Canadian banks which have made loans to nickel facilities overseas, e.g. The Bank of Montreal's loan of $13.5 million to INCO for its Indonesian project.

Table 3.20 lists all such exports of Canadian capital for nickel projects ranging from mining through to refining and other further processing. While the list is probably far from complete, it is also very difficult to divide Canadian source capital from foreign source capital owing to the fact that several of our nickel companies have considerable foreign equity ownership. For instance, in the Dominican Republic where Falconbridge Nickel Mines has invested some $195 million, about $10 million of this was equity contributions by Falconbridge itself, a company resident in Canada, but controlled by foreign interests. Looking only at the equity portion, most of this would originate from retained earnings, and some of these retained earnings were derived from off-shore operations.

It also should be noted that these capital expenditures cover a time period prior to 1946 (in the case of INCO since the early 1900's) and, therefore, assumptions regarding which rates of inflation to use over the various time periods can have a considerable impact on the order of magnitude of the estimated total capital expenditures.

This list is limited to expenditures for mining through to refining and it does not include stainless steel processing plants other than that of Cuba (which is a stainless steel plant that will consume *primary* nickel.)

Despite such qualifications, it is safe to say that the $1.8 billion (1976 Canadian dollar) total is likely to be on the low side, and possibly closer to $2 billion in actual fact.

As an illustration of how low these estimates could be, consider capital expenditures for INCO and Falconbridge, including an accurate breakdown of capital expenditures in Canada and elsewhere for INCO over the period 1967-76. It is very apparent from the following chart how rapidly capital has been exported out of the country. For instance, in 1967 INCO spent $15 million outside of Canada, and this escalated to $369 million by 1976 for a total of $922 million in the ten year period out of $2168 million. Or, in percentage terms, from 10.3% in 1967 to 80.4% in 1976. In order to complete the table of total capital expenditures some assumptions had to be made regarding the split of exploration expenditures for both INCO and Falconbridge outside of Canada, and within Canada, over the time period 1960 to 1976 (assumed to be negligible prior to 1960). For instance, in the case of INCO it is assumed that prior to 1965 exploration expenditures outside of Canada totalled 20%. This gives a reasonable and possibly understated picture of Canadian capital migration for nickel-related projects.

It is tempting to assume that such export of capital is to Canada's detriment. However, before arriving at this conclusion the reader should consider two important facts. For one, in the early days of the nickel industry it was much easier to extract nickel from sulfide ores than from laterites. This was directly related to the higher grades and ease of concentrating sulfide ores, plus their closer proximity to markets. Such advantages overcame the obstacles of underground mining and the metallurgical separation from copper. It was most logical, therefore, that early capital investment swung from New Caledonia to Sudbury. By the mid 1960's, however, higher North American labour costs, coupled with advances in bulk material handling and greater flexibility in extracting and marketing nickel products from lateritic ores, rendered such deposits more attractive. Generally speaking, these deposits are located in geographical regions which have abundant low cost labour and are close to ocean ports. Consequently, the latter has been developed with relatively high cost capital (in current dollars) as a trade-off against lower labour costs and often more favourable taxation. Therefore, Canadians themselves are partially responsible for this capital migration.

Secondly, it must be recognized that governments world wide are becomming more interested in their domestic mineral development. Consequently, if a Canadian nickel company did not develop such resources, incentives would likely be available for others to do so. Preservation of Canadian jobs depends largely on maintaining Canada's share of the market, if not by domestic sources, at least by Canadian based companies.

INCO LIMITED

CAPITAL EXPENDITURES

$ Millions

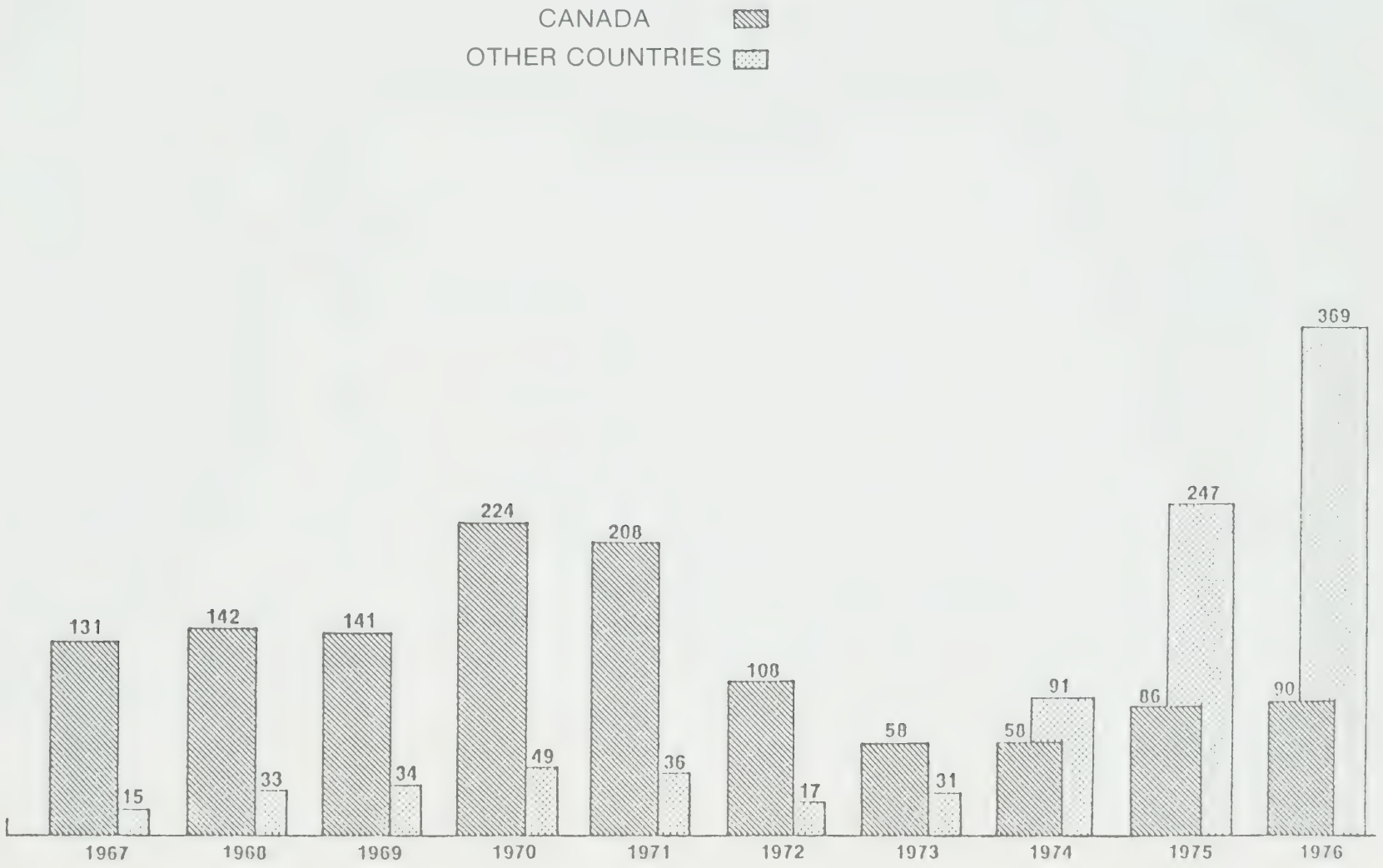


TABLE 3.20

PARTICIPATION in overseas nickel mining projects, refineries, rolling mills, & stainless steel plants by Canadian mining companies, Canadian banks and Canadian Government agencies

Company, Bank or Agency	Location of nickel mine or stainless steel plant	Nature of Interest	Canadian Expenditures $ Million (Canadian dollars except where noted)
1. Inco Ltd.	Indonesia	(1) Owner of mine, smelter complex	$875 (1978)
2. Inco Ltd.	Guatemala	(3) Joint venture with Hanna Mining, U.S.A.	231 (1977)
3. Inco Ltd.	U.S.A.	(1) Huntington, W. VA. & Burnaugh, Ky., U.S.A. Wrought nickel & high-nickel alloys	200 E
4. Inco Ltd.	Overseas	Exploration projects, New Caledonia, etc.	80 E
5. Inco Ltd.	Clydach, Wales	(1) Refinery expansion	13.8 (U.S.)
6. Inco Ltd.	Petsamo, Finland (now Pechenga in Soviet territory)	(1) Sold developed reserves to USSR in 1950's	6.7 (1939)
7. Inco Ltd.	Impala	(2) 10 per cent interest	0.5 (1976)
8. Falconbridge Nickel Mines Ltd.	Dominican Republic	(3) Joint venture with Armco Steel, U.S.A.; integrated ferronickel producer	195 (1971)
9. Falconbridge Nickel Mines Ltd.	Ivory Coast	(1) Negotiating joint venture with government	23. I
10. Falconbridge Nickel Mines Ltd.	Norway	(1) Development of nickel mining project	
11. Falconbridge Nickel Mines Ltd.	Philippines	(1) Feasibility studies several deposits	
12. Falconbridge Nickel Mines Ltd.	Other Overseas	Various exploration projects	
13. Falconbridge Nickel Mines Ltd.	South Africa	(2) 24.5 per cent interest in Western Platinum Ltd.	11.4 (1976)
14. Falconbridge Nickel Mines Ltd.	Norway	(1) Refinery expansion and modernization	2.8
15. Sherritt Gordon	Philippines	(2) 11 per cent interest in Marinduque Mining & Industrial Corp.	7.0
16. Sherritt Gordon	Indonesia	(3) 9 per cent interest in joint venture in P.T. Pacific Nikkel Indonesia with Hoogovens Steel, et al, sold to Amoco Minerals	3.5
17. Bank of Montreal	Indonesia	(4) Loan guaranteed by U.S. Export-Import Bank for Inco Ltd.'s Indonesia project	13.5 (included in 1)
18. Government of Canada	Cuba	(4) Funding for stainless steel plants	150.
19. CIDA (Government of Canada)	Botswana	(4) Funding for power plant	5. + technical assist.
		TOTAL	**$ 1.8 billion** (1977 $)

Notes: E — Estimates
(1) Owner (3) Joint Venture
(2) Part owner (4) Funding/grant

3.21 Soviet Nickel — Mine Output

The Soviet Union is the world's second largest producer of nickel, after Canada. Total refined production in Russia in 1977 is estimated as *160,000 metric tons*; (1976 — 151,000 metric tons of refined nickel). Expansion to a capacity of 168,000 tons of nickel in 1977 and 190,000 tons in 1980 is expected.

Output from U.S.S.R. nickel mines more than tripled between 1950 and 1970. Soviet output of nickel increased by about 50 per cent during 1971-75. About 70 per cent of Russia's total nickel and platinum group metals output comes from the Noril'sk'-Talnakh mines. In 1947, only 30 per cent came from Noril'sk. Of the remainder, the Pechenga and Kola peninsula mines produce a little less nickel than the nickel oxide deposits of the Southern Urals.

	1972	1973	1974	1975	1976
	'000 metric tons				
Refined Nickel Output	130	130	134.5	143	151
Mine Output Nickel Content	110	115	120	125	130

Sources: Metallgesellschaft; Imetal Annuaire Statistique Minemet 1976.

The U.S. C.I.A. estimated in 1977 that the U.S.S.R. will depend on such metals as gold and the expensive platinum group to boost its export earnings to compensate for lower oil exports. Virtually all of the Soviet platinum group metals are by-products of *nickel* mining.

About 10 per cent of total Soviet copper output is a by-product of nickel mining.

SOVIET EXPORTS

LOOKING TO THE FUTURE, THE SOVIET UNION WILL CONTINUE TO BE AN IMPORTANT EXPORTER OF NICKEL METAL FOR MANY YEARS, BASED ON BOTH SOVIET AND CUBAN CONCENTRATES.

The Russians probably regard nickel as a strategic material and therefore do not include it in published trade figures. We must therefore study the trade statistics of recipient countries.

TOTAL IMPORTS OF NICKEL METAL FROM THE SOVIET UNION

(by major importing countries in the West — see Appendix)

The Soviet Union has a nickel sales policy which serves its own purposes and not the users of the metal. In times of reasonable demand it elects to sell or withhold metal while being quite unable, of course, to control the ebb and flow of industrial demand itself in the West.

SOVIET ORE RESERVES

The Soviet Union reputedly has reserves of under 10 million metric tons of nickel in ore deposits (A. Sutulov). (There is a shortage of nickel reserves in the Kola Peninsula). Associated platinum group metals reserves in ore are estimated as 6,220 metric tons. The U.S.S.R. is the world's largest producer (by weight) of the P.G.M.'s, (87 metric tons, in 1976), and output is expanding.

NICKEL MINING LOCATIONS

NORIL'SK, (Latitude 69°N, Northwestern Siberia)

This is the northernmost town of significant size in Russia, after Murmansk. It is a nickel-copper platinum mining town. There is no daylight for 47 days each year in Noril'sk, which is located in the Arctic Tundra. For about 250 days a year snow lies on the ground, which is a rather long period of snow-slush cover.

The population of Noril'sk went from 109,000 in 1959 to 156,000 in 1974. The opening of new nickel-platinum sulphide mines and the expansion of the smelter-refinery complex in the mid-1970's has caused the expansion.

Complex ores in the area yield nickel-copper, cobalt, gold, silver, the platinum group metals and some tellurium and selenium.

Nickel production began in 1942, cobalt in 1944 and copper in 1950.

Noril'sk has central streets of buildings of steel and concrete, built on the permafrost. Permafrost is a permanently frozen sub-soil with a temperature at a depth of 35 to 50 feet of 32° F.

A railway runs about 110 kilometres WNW of Noril'sk to Dudinka, an inland river port on the Yenisey in the wooded tundra zone. It is double tracked and electrified. Dudinka used to be the chief Tsarist centre on the river. Dudinka is open four months of the year, or longer with icebreakers. The two towns were first linked by rail in 1937. Western tramp steamers regularly sail past Dudinka on their way upstream (southwards) to load timber at Ingarka, which is open 106 days, July 17 to October 31.

Coal and *uranium* are also mined nearby.

Two natural gas pipelines, running nearly 200 miles from Messoyakha, Fakel and Tazovskoye to the West, supply Noril'sk, supplanting some locally mined coal. Construction of a third Messoyakha-Noril'sk pipeline began in November, 1976.

TALNAKH

Large new ore deposits were discovered 800 feet below the surface, (a greater depth than Noril'sk), in the 1960's at Talnakh, on the banks of the Talnakh river, some 25 to 30 kilometres to the North-east of Noril'sk.

A new rail line was built in the 1960's, 25 to 30 kilometres in length, running to the new copper-nickel-platinum mines and town of Talnakh. Mine output goes to the Noril'sk smelter-refinery, (for electrorefining).

Talnakh is now the major ore producing area for the Noril'sk smelter-refineries. The second smelter-refinery there has been under construction for several years and may be ready by the end of 1977. It will recover sulphur as a by-product.

When this complex is ready, a large part of the Noril'sk-Talnakh area ores can be treated at Noril'sk. For some time the currently excess ore has been sent via the port of Dudinka by sea through the Artic Ocean to the port of Murmansk on the Kola peninsula, a sea ice journey of some 1,500 miles, for treatment at the Monchegorsk smelter-refinery. These deliv-

eries are to be increased. About 200,000 tons of ore have been shipped per navigation season. The metal content was 3.1 to 3.5% Ni, 0.11 to 0.14% Co., 2.8 to 3.2% Cu with some precious metals. Dudinka is open four months in a year, or 7 to 8 months with icebreakers.

SNEZHNOGORSK ("Snow Mine or Mountain")

A new town, growing fast at *Snezhnogorsk*, South of Noril'sk at the foot of the Taimir peninsula, serves a mining area rich in nickel-copper-cobalt-platinum ores. The suffix "*-gorsk*" means "mining town" in Russian. This is similar to the use of the German word "-berg". The main street of Snezhnogorsk is appropriately named "68th Parallel". In 1968 there were already 10,000 people there. Some worked at the nearby hydro-electric plant, (Khantayka).

The Khantayka hydro plant nearby supplies some power to *Noril'sk*. The Khantayka hydroelectric station provides 440,000 KW (from late 1972) and another one of the 500,000 KW is planned on the Kureyka river in the same area. The workers settlement for Khantayka is at Snezhnogorsk. The hydro station was the first major construction on permafrost in the far North under severe winter weather conditions with snowstorms lasting for days on end with gale force winds and frost under -60° C. This experience may be useful in building hydro stations on the Lena and Kolyma rivers in the Soviet Far East.

Temperatures

The date of *freezing* of rivers is September for the Taimir Peninsula, so for the Noril'sk area it might be early October.

At the mouth of the Yenisey river, which the Russians reached in 1610, (Western side of the Taimir peninsula), about 300 miles North of Noril'sk, the *thaw* does not set in until *the second week of June*. The average July temperature there is 40 to 50 degrees F.

The Yenisey river flows due North to the Arctic from the Southern Soviet Union and is some 3,000 miles long.

Cap Chelyuskin on the Taimir peninsula is *the most northerly point* in mainland Russia. The strait that it borders is open only 62 days a year, August 7 to October 8. This is about the latitude of the northern tip of Prince Patrick Island, N.W.T., Canada.

A.1 SULPHIDE NICKEL MINES IN THE U.S.S.R.

THE NORIL'SK GORNO METALLURGICHESKI KOMBINAT (COMBINE) IN NORTHWEST SIBERIA

n.b. A very high priority is given to the Noril'sk development in Soviet economic planning.

a) NORIL'SK SMELTER-REFINERY

Recent expansion has been rapid. Construction continued at the *1 billion rouble* Nadezhda copper-nickel base metal refinery complex, (consisting of 15 plants), near Noril'sk, a major project of the 1976-80 5 Year Plan, continues with the technical assistance of Finnish companies.

The "first stage", originally due in 1974, has been rescheduled for 1977. Most of the increased Soviet nickel output is to come from the Noril'sk area refining complex. A Finnish consortium designed and is assisting in the assembly of the large new furnace and associated equipment. Outokumpu Oy of Finland was to deliver flash-smelting plants for nickel and copper by 1977, with an annual capacity of 550,000 metric tons of nickel concentrate (100,000 tons of nickel) and 650,000 tons of copper concentrate, (200,000 tons of copper). Equipment worth over U.S. $6 million is being delivered by Suomen Puhallintehdas Ltd. of Finland to the Noril'sk copper and nickel plants. Autoclaves are to be used at Noril'sk for the first time in the Soviet non-ferrous industry. Sulphur will be recovered as a by-product.

"Second stage" details are not known. Silver and cobalt are also important by-products. Noril'sk is the largest cobalt-producing centre in the U.S.S.R.

Construction of the Noril'sk-Nadezhda road-rail complex of about 20 miles has been completed.

A second concentrator, "No. 2", was under construction at Noril'sk in 1976. The laying of the 22 mile pipeline for concentrate shipment from the mill to the new complex began in 1976. It is planned for completion by 1980. Ingersoll-Rand of the U.S.A. has signed a U.S. $14 million contract for delivery of 10 large vertical reciprocating pumps to be used to transport abrasive polymetallic concentrates through pipelines, (presumably at Noril'sk).

b) MINES IN THE RUDNAYA GORA AREA

The deposits are similar to those of the Sudbury Basin in Ontario, Canada. Orebodies are at intrusive contacts (mainly diabase and gabbros). Cupriferous pentlandite orebodies, averaging typically 0.5% Ni, 0.8% Cu. The P.G.M.'s comprise palladium 60%, platinum 30%, ruthenium 6%, rhodium 2%, iridium 2% and osmium less than 1%. The Pd/Pt ratio can go as high as Pd10:1Pt, in places.

Two types of orebody are worked:

— low grade 0.1% to 0.3% Ni disseminated bodies and

— high grade veins and lenses of up to 1.23% Ni, 2.16 Cu and 0.1% Co.

Plans call for P.G.M. and nickel output at Noril'sk to rise by 1980 by about 80% over 1975. Cu-Ni-Pt "reserves" in the Noril'sk area have increased in quality and quantity by 50% in the last 10 years. 1,662 geologists (20 teams) were employed there in 1976. Prospecting is being carried out North of Noril'sk.

i) at *NORIL'SK — 1* Sulphide deposit:

a) Underground — Zapolyarnyy, ("Far Arctic"), (the original mine)

b) Open Pit — Medvezhiy Ruchey (Medvezhiy is Southwest of Noril'sk city)

The ore grades average 0.75% Cu, 0.5% Ni, perhaps 1 per cent Cu and up to 11 g. platinum group metals per metric ton, (Sutulov), mainly palladium and platinum

ii) At *TALNAKH* sulphide deposit, North of Noril'sk

Two undergound mines:

a) Mayak — reached its planned capacity in 1973, and was probably then producing about half of the Noril'sk area output.

b) Komsomol'skiy (new mine) (1968?) larger than Mayak.

Grades average about 3% Cu, 1.5% Ni and up to 11 g. platinum group metals per ton.

iii) at the *OKTYABR'* sulphide deposit (near Talnakh):

The new Oktyabr'skiy ("October") underground mine under development since 1969; (*Third stage* put into operation in December, 1975. *Fourth stage*, for the full planned capacity, is under development and should be

ready by *1980*, when *IT WILL PRODUCE 50% OF THE TOTAL ORES IN THE NORIL'SK AREA.*

THE OKTYABR'SKIY ("OCTOBER") MINE IS ALREADY THE LARGEST UNDERGROUND MINE IN THE SOVIET NON-FERROUS INDUSTRY.

Depth is about 1,000 metres.
Grades average 3.65% Ni, (one report says 2.5% Ni), 4.7% Cu, 0.13% Co and some platinum group metals.

iv) Development of the Glubokiy underground mine, in the Taimir peninsula continues. It is planned for completion in 1984.

At the fourth underground mine in the Talnakh area, where development commenced in 1973, sinking of the 1,500 metre deep "Taymyr" shaft started in April, 1977.

KRASNOYARSK

	1860	1926	1968	1973	1974
Population	9,000	72,000	592,000	707,000	728,000

Krasnoyarsk, founded in 1628, on the Yenisey river, 900 miles South of Noril'sk, latitude 51 degrees North, the largest city in Eastern Siberia, has the largest capacity hydroelectric power station in the world, (6 gigawatts, or 6 million KW), which began production in January, 1972. A radio-technical school of The Soviet Air Defence is located at Krasnoyarsk. The Trans-Siberian Railway passes through the city.

To the West, above the city is a 1,200 yard long, 420 feet high dam and a 2,000 square mile reservoir. Krasnoyarsk is about 500 miles from the Chinese border.

This city of three quarters of a million people has modern

i) electric steel mills

ii) aluminum smelter (one of the largest in the world, 400,000 tons of aluminum per annum)

iii) non-ferrous and *precious metal* refineries.

The *world's largest P.G.M. refinery* is at Krasnoyarsk, South of the Noril'sk area nickel mines, source of over 70 per cent of Russia's P.G.M.'s. *The platinum group metals-bearing sludges are sent from the Noril'sk smelter to Krasnoyarsk for refining* to the individual commercially pure metals. Capacity of this electrolytic refinery complex is believed to be over 90 tons of P.G.M.'s a year.

The drive to open up new nickel mines and increase smelter output will increase the output of by-product P.G.M.'s in Russia at a rate of 4 to 5 per cent a year — U.S. B. of M. estimate.

A. 2 MURMANSK-PECHENGA-NIKEL' -MONCHEGORSK AREA

The U.S.S.R has been negotiating with French, West German, Finish, British and Japanese companies for equipment for a planned nickel smelting plant near Murmansk.

Murmansk is the largest polar city in the world at a latitude of 69° 10/ N, 33° 30/ E, and the largest port within the Arctic Circle. The comparatively warm Gulf Stream water from the Atlantic gives the Murmansk area some of the mildest winter weather, relatively, to be found anywhere in the Soviet Union. The bleak and barren Murman coast is a region of granitic cliffs 1,000 feet high, but has many excellent harbours. There is no real daylight for over 40 days each year. Population in 1974: 347,000 (in 1939: 117,054). It was a small fishing hamlet with a few wooden buildings in 1915 when the British decided that they could supply the Tsarist armies through it. World War II helped it grow too, with its lend-lease shipments of war materiel shipped from the U.S.A., U.K. and Canada with serious losses of convoy ships, cargoes and Allied sailors. Most of the war materiel for the Soviet Union was unloaded at Murmansk in the 1941-2 period. Allied ships headed for Murmansk also carried metals like *nickel* which were badly needed in Russia in the manufacture of special alloys and hardened steel. Canada also gave the U.S.S.R an icebreaker.

The year-round ice-free Arctic port of Murmansk is situated on the East shore of Kola Bay at the head of the wide Kola fjord, 65 kilometres from the sea, near the Northern end of the Kirov railway on the Kola peninsula, (which forms the Russian border with Northern Norway and Northern Finland). The new Soviet-Finnish frontier is delineated so that Finnish territory is no closer to this railway than 75 miles at any point. In 1976, some 200,000 tons of *nickel ore* was *brought to Murmansk by sea from* the port of Dudinka serving *Noril'sk*, 1,500 miles away and unloaded for Monchegorsk. Almost the entire route is in waters of less than 100 fathoms. The railway connects Murmansk to Leningrad, 800 miles away, *Monchegorsk*, Pechenga, Nikel and Archangel. With regard to *power* supplies, a marine power station utilizing tidal energy is in place on the Kola river near Murmansk. The pilot installation is about 4 times the size of the Rance facility in France, but the U.S.S.R. may not have reached firm decisions on whether to proceed with larger projects in the White Sea and the Bay of Okhotsk.

Murmansk contrasts vividly wih the port of Archangel, 400 miles further to the *South East*, which is frozen up from early November until late April. Archangel was Russia's first seaport, founded in 1584. Archangel can be kept open by icebreakers during the winter. The shipyards at Severodvinsk, (formerly called Molotovsk), 64.27° N, 39.58° E, population 124,000 (1968), a new outport and naval base located 30 miles North West of Archangel, became, in the 1960's the largest submarine building centre in the world. The first Soviet nuclear submarine was built there in 1959. All six slips are covered and heated.

The Kola Peninsula and Pechenga are believed to be covered by extensive military installations and so one would guess that the Soviet authorities would not permit visits to the *nickel mines and smelters* there, although foreigners have been to Murmansk. Foreigners have been allowed to *visit* the *Noril'sk mines* 1,500 air miles to the East.

The Soviet Northern Fleet, (Severnyi Flot), is based at the ice-free port of Severomorsk, ("Northern Sea"), the H.Q. of C.-in-C. Northern Fleet, on the Kola river inlet, a few miles North of Murmansk, and at Polyarnyy or Polyarnoe, ("Arctic"), which is the submarine base, fully equipped with pens, located on the wide Kola inlet downstream from Severomorsk. Northern Fleet has many more submarines than any of the other three Soviet fleets. The new 35,000 ton largest Soviet aircraft carrier "Kiev", flying 25 "Forger" Yak vertical take off/landing jet fighters is based at Murmansk.

Murmansk has important ship-building and repair yards and is also the main base of the Northern Sea Route Administration (Glavsevmorput) Merchant Fleet and the fishing and ice-breaker fleets which travel the Arctic routes, including those carrying *nickel ores*. Russian merchant ships, convoyed by ice-breakers and observation planes, travel the complete Arctic Ship Route only from mid-July to the end of September. The nearest limit of spring pack ice to Murmansk is 200 miles to the East.

The Institute of Murmansk which is associated with the Institute of Oceanology of the Academy of Sciences, Moscow, specializes in marine biology.

KOLA PENINSULA AND PECHENGA AREA MINES

(which together produce about 27,000 metric tons of nickel out of total U.S.S.R. mine output of nickel. Smelter-refinery capacity at Monchegorsk is about *twice* that.)

Sixty miles West of Murmansk, there are nickel-copper sulphide deposits being mined at the small port of *PECHENGA*, (formerly Petsamo), which is ice-free throughout the year, lying in the Petsamo fjord South of the Russian port of Liinahamari, (Linakhamari, Litsnayamari), and at *NIKEL'MURM*, further South, both in former Finnish territory, each located less than 10 miles from the Norwegian border. The Norwegian city of Kirkenes is only 30 miles from Pechenga.

The Pechenga (Petsamo) mine was developed by the Mond Nickel Co. of London, England, wholly owned subsidiary of *International Nickel Co. of Canada Ltd.*, in the 1930's, when it was in Finnish territory. It was intended that the nickel matte produced would be shipped to Canada for refining, but in 1939, the Soviet-Finnish war broke out and mining and construction at Petsamo were halted.

WAR FOR THE NICKEL MINES

In the Spring of 1940, the Soviet government had exerted great pressure on Finland to replace the foreign concessionaire operating the Finnish Petsamo nickel mines, The International Nickel Company of Canada, to ensure Russian control.

In January, 1940, the French Commander-in-Chief, General Gamelin, produced a plan for an Allied landing at Petsamo.

Germany had *very limited sources of nickel* — vital in armaments — during World War II. Hitler's objectives in supporting Finland and invading Northwest Russia in 1941 included cutting the rail line from Murmansk to Leningrad, and acquiring control of the nickel mines and smelters of the Kola Peninsula-Monchegorsk region which would supplement the Petsamo nickel output and deny the nickel to the Russians.

Hitler's plan was that the Kola Peninsula *would become a part of German territory after the War*, because of the nickel mines there.

From June, 1941, when the Germans attacked, the Red Army used North Russian and Siberian troops of General Frolov's 14th Army and the 7th Air Army to oppose General Dietl's German 19th Mountain Corps and later 20th Mountain Army. *Monchegorsk* and its *smelter* were *captured* by the Germans and Finns, but Murmansk remained in Russian hands. The Petsamo area was occupied by German troops during World War II.

During the World War II years 1939-42, Petsamo nickel matte, (about 10,000 metric tons of nickel contained a year) and some ore went to Germany, where it was *refined* to metal *by Badische Anilin* at Ludwigshafen. The British bombed German-occupied Petsamo in 1942. Not until October 15, 1943, did the Red Army finally move troops into the Petsamo area.

Petsamo and North coast Finland were *ceded to the U.S.S.R.* in September, 1944, by agreement with President Roosevelt and Prime Minister Churchill. Petsamo became Pechenga. The U.S.S.R. paid the *International Nickel Company of Canada Ltd.*, U.S. $20 million *compensation for* the appropriation of the Pechenga (Petsamo) mine, remitted in four annual instalments during the 1950's.

A.2.1. PECHENGANIKEL COMPLEX

i) Smelter at Pechenga. Englargement and renovation of concentrator and smelter continues.

ii) *Four Small Underground Mines*	*Two Small Open Pit Mines*
a) Kaula (Kaulatunturi) — *In-International Nickel of Canada Ltd.* sank the first adit and vertical shaft in the 1930's and started to build a smelter and a hydro-electric plant at Lake Inari to produce low cost electric power.	a) Kaula
b) Kammikivi	b) Kammikivi
c) Kotselvaara	
d) Northern	

The ore reserves developed by International Nickel Company of Canada prior to 1940 at Petsamo were around 8.5 million tons, said to spread over 10 deposits, and graded 3.8% to 4.0% Ni, 1.8% Cu and 0.08 troy ounces of precious metals per ton. Current mining grade is *only 1.8% Ni*, it is believed.

The new "Northern" mine of this complex came on stream in December, 1975. The ore of this deposit is said to be *rich in nickel*. No other details known.

A deposit of copper-nickel ore was discovered at Zapolyarnyy in 1974. The U.S.S.R. was negotiating with Finnish, West German and Japanese firms to supply equipment for a nickel smelter — the raw material to come partly from Noril'sk.

A.2.2 SEVERONIKEL ("NORTHERN" NICKEL) COMPLEX, KOLA PENINSULA, EAST OF PECHENGA

MONCHEGORSK SMELTER-REFINERY

The nickel-copper smelter-refinery is inland on the Kola Peninsula at *MONCHEGORSK*, 65 miles South of Murmansk, (population 53,000 in 1968). This electro-refining complex also treats some of the nickel oxide ores and nickel-copper ores brought by sea to Murmansk from *Cuba* and from *Noril'sk*, (about 1,500 miles due East). About *200,000 tons of ore were shipped* there from Noril'sk in 1976. The Noril'sk deliveries are to be increased. This refining complex accounts for the bulk of the combined Kola Peninsula-Pechenga mine output. Both areas are on the edge of the Northern limit of wooded country.

CUBAN MATERIAL FOR THE U.S.S.R.

The Soviet Union is said to refine up to 65 per cent, say 20,000 to 25,000 metric tons, of Cuba's nickel output — at *Monchegorsk* in Russia it is believed. Czechoslovakia may be taking the balance. *Russia* is financing a U.S. $600 million expansion of Cuban nickel production — target 90,000 metric tons of nickel a year by 1985, including the new Soviet Gipronikel designed plant at Punta Gorda to produce 30,000 tons a year of nickel plus cobalt. An eventual Cuban mine output capacity of 150,000 tons is planned.

MINES

The original mine (underground) was Nittiskumuzh'ye, late 1930's. Now has both open pit and underground mines. The large scale low grade (less than 1% Ni) Zdhanovskiy open pit mining and concentrating complex is the largest of the operations in this area. It also treats ores from the Monchetundra and Zapadnyy ("Western") mines.

The Monchegorsk area ore may average about 0.7% Ni, 0.4% Cu and some cobalt and platinum group metals. The ore at the Lovnozersk deposit, (at Lovozero?, East of Monchegorsk), averages 0.9% Ni, 0.5% Cu, 0.94% Co, with some platinum group metals.

There is a shortage of nickel reserves in the Kola Peninsula.

Some of the Kola Peninsula nickel-copper mines produce silver as a by-product.

B. OXIDE NICKEL MINES IN THE U.S.S.R.

(which produce about 31,000 metric tons of nickel out of total U.S.S.R. mine output of nickel.)

B.1 IN THE UKRAINE

Pobuzhye

Ferronickel Plant inaugurated in 1973 after 10 years of construction. Produces about 10,000 metric tons of nickel in *ferronickel* a year in modern thermoelectric furnaces. Major breakdowns occurred in 1974.

Feed: *lateritic* ores (1.4% Ni) from the Kirovograd region, lying West of the Dnieper river in Ukraine. Name of mine not known.

B.2 IN THE URALS

YUZHURALNIKEL OR YUZHNO ("Southern") URALS COMBINE COMPLEX

(renovated during 1971-76 period at a cost of 112 million rubles, with output increased about 16%)

— includes Revda, 25 miles from Sverdlovsk, (formerly Yekaterinburg), South Central Urals. *The Institute of Mining* is at Sverdlovsk, population 1,122,000 (1974).

— the first discovery of nickel in Russia, in the early 19th Century, was at Revda.

Rezh(evskiy) Smelter (1935), 45 miles NE of Sverdlovsk

— produces matte from low grade oxide ores from the mine, (since 1965), at Oktyabr'skiy ("October"), which is refined at Ufaley.

— losses during recovery of nickel from 1.5% Ni ore in 1974 were up to 20 per cent.

Ufaley Smelter (1934)

— Russia's first nickel refinery

— original capacity: 3,000 metric tons a year

— uses process similar to New Caledonia and German methods.

Feed from the Verkhniye-Ufaley mines, 55 miles South of Sverdlovsk, (between 1.5 to 2% Ni). Reserves are not large, and may be near exhaustion.

The development of the first stage of the Shcherbakovskiy open pit, the largest in the Kimpersay nickel ore administration in the Yuzhuralnikel complex, was completed by December, 1976, to produce 500,000 tons of ore in 1977. The pit should be fully operational by end-1980.

B. 3. ORSK COMBINE near Southern Limit of Urals

Orsk-Khalilovo Smelter-Refinery (1938)

Feed for the Orsk-Khalilovo refinery comes from the Khalilovo, Akkermanovka and Aktyba (Aktyubinsk) area mines.

Khalilovo, 25 miles NNW of Orsk, population 237,000 (1974). (reserves: 4 million tons nickel; grade about 1.5% Ni), is the largest sources for the Orsk plant. The Khalilovo Smelter, (Orenburg Oblast), takes the feed from Buranovskiy-Burukhtal.

Akkermanovka is 15 miles due West of Orsk.

Aktyubinsk, population 159,000 (1972), is 90 miles SW of Orsk. Aktyubinsk and Burukhtal are both in Kazakhstan.

B. 4. BURUKHTAL COMBINE

Burukhtal, 100 miles ESE of Orsk, may be the *richest* single *lateritic* deposit of nickel in the Urals, 1.0% Ni.

A small open pit came on stream at Burukhtal in May, 1976. The ore, 0.88% Ni, 0.08% Co, is smelted in an electric furnace.

Buranovskiy mine (1968).

Foreign credits exceeding U.S. $200 million may be needed to develop major new discovery. Japan may assist.

B. 5. URALS — NICKEL MATTE

Roskill states that these Urals *lateritic* ores are smelted to produce a low grade furnace matte with the following approximate compositions:

	Orsk and Ufaley	Rezh
	%	%
Nickel	17.	10.
Iron	56.	65.
Cobalt	0.7	0.4
Sulphur	18.	20.

NEW CALEDONIA



December 31, 1976

- CLOSED AREAS
- CLOSED TO PROSPECTING & EXPLORATION
- REGULATED AREAS

SCALE

0 10 20 30 MILES

10 20 30 Km

3.22 New Caledonia (original name Balade)

a French-controlled Pacific island 1,250 miles NE of Australia; area 7,374 square miles; 220 miles long. Discovered by British Captain Cook in 1774. Annexed by France in 1853. One of the richest of the Pacific islands in mineral resources. From 1871 to 1896 it was a convict settlement. Population: 68,000 in 1956; 100,579 in 1970.

Only Cuba has higher reserves of nickel in ore. Production from these large deposits began in 1875, years before nickel was discovered at Sudbury, Ontario. New Caledonia was the world's largest producer of nickel until 1905 when it was passed by Canada. The island has been the world's third largest producer ever since the U.S.S.R. achieved second place in the 1960's.

The nickel ores are free of arsenic.

SLN

"Societe Metallurgique Le Nickel, S.A." (SLN) is the largest producer on the island, mining ore and producing ferro-nickel, plus a small quantity of matte. The company's financial structure was changed in November, 1974, (see diagram). SLN is jointly owned by the State-controlled Aquitaine Company and by the Imetal Company.

Has open pit mines at Nepoui, Poro, Thio and Kouaoua. Ore grades 2.7 per cent (Ni + Co) (down from the 9 per cent average grade of the early years).

SLN intends to increase its New Caledonia mine output to at least *90,000 metric tons of nickel a year*.

However, SLN *cut back mine production* in 1976 by 9,000 tons to 61,700 metric tons of nickel and further reduced output to about 70 percent of capacity early in 1977. Total New Caledonian mine production since 1967 had varied from about 100,000 to 137,000 metric tons a year contained nickel, depending on markets. About 40 per cent of the ore output is exported to Japan.

SLN stockpiled 20,000 metric tons of nickel output during 1975, making total inventory at end-1975 40,000 tons of nickel and 45,000 to 50,000 tons at end-1976. In October, 1977 SLN stated that it would not increase its nickel stocks in 1978 above the level at that time thought to be equivalent to about six months output.

About 50 to 60 per cent of the island's ore output is processed on the island to matte. Matte is mainly exported to France and Japan. Some SLN nickel matte has gone to *Sherritt in Canada* for refining and some to the AMAX, Louisiana, U.S.A. nickel refinery. The bulk of the ferro-nickel is exported to France, Japan and the U.S.A.

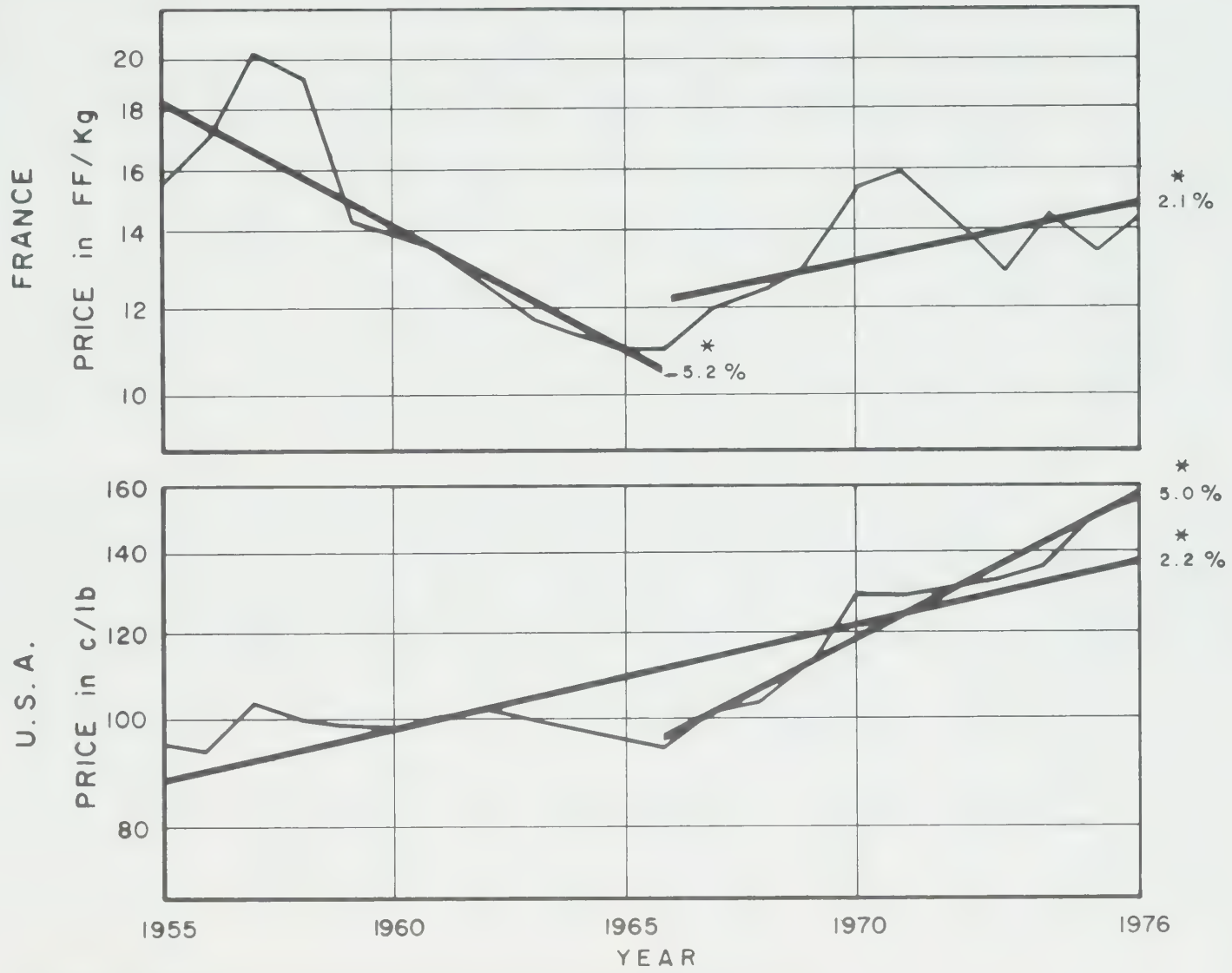
Smelter-Refinery at Doniambo

The current capacity of the SLN smelter, in New Caledonia, the world's largest ferro-nickel plant, is 71,000 metric tons a year of nickel in ferro-nickel (Grade I, 29% Ni) and in nickel matte (over 70% Ni). The latter goes to SLN's Le Havre, France plant, for refining to 12,000 tons per annum of nickel rondelles, (99.25% Ni, 0.45% Co).

Doniambo is being expanded to 100,000 metric tons by *1980* and to *110,000 metric tons of nickel* in ferro-nickel and matte a year by the early 1980's.

Expansion costs are currently estimated at over U.S. $250,000,000.

PRICES OF NICKEL
(In Constant 1970 Dollars)



* Positive and Negative per annum changes in prices for periods 1955-65 and 1966-76 (FRANCE), 1955-76 and 1966-76 (U.S.A.).

POWER

All of the island's hydroelectric potential has been tapped. Oil imports for nickel smelting add considerably to the cost.

FRANCE — REFINING

SLN has an old refinery in the port of Le Havre, France, that can produce 12,000 metric tons a year of rondelles (99.3% Ni), nickel oxide and some nickel salts from New Caledonian matte.

SLN was said to be planning a new refinery at Le Havre (15,000 metric ton capacity) to produce refined nickel (99.95%) from Doniambo matte, so that SLN may compete with electrolytically refined and carbonyl refined quality nickel produced in Canada.

Independents

Le Syndicat Independant des Mines, a group of independent ore producers sell some ore to SLN, but mostly they sell to the Japanese, who use it to make ferro-nickel. The Syndicat produces about 35 per cent of the island's nickel-ore output.

New Caledonia's Mine Output of Nickel (metric tons)

1969	1970	1971	1972
116,800	138,500	150,900	108,100
1973	1974	1975	1976
115,900	136,800	133,300	118,900

COMPARISON OF NICKEL PRICE IN DOLLARS AND IN FRENCH FRANCS

Price	1965	1969	1970	1973
$ U.S. per pound at year end	0.78	1.28	1.33	1.53
French francs per kilo at year end	8	15	16	14

It can be seen from the above table that, owing to currency exchange rate fluctuations, producers basing their nickel product prices in French francs had an advantage during the period 1965 to 1970, but were at a disadvantage from 1970 to 1973. In terms of French francs, the nickel price fell in 1973. For this reason, as well as the onerous New Caledonian tax system, French government assistance was obtained and resulted in the reorganization of the Rothschild interests into Imetal and associated companies.

Taxation

The onerous New Caledonian ad valorem tax system of 9 to 11 per cent on imports and exports was changed towards the end of 1975.

The new tax is a *50 per cent tax on profits*, made retroactive to January 1, 1975. This has stimulated new mining projects. SLN was to pay a 6 per cent *tax on sales* in 1975 and 3 per cent in 1976.

PROJECTS

Ownership

Companies working deposits in new Caledonia must be more than 50 per cent French. The state-owned B.R.G.M. is involved in joint ventures with AMAX and others.

COFREMMI (Cie. Francaise Metallurgique et Miniere)

90 per cent of the capital of Cofremmi is now owned by the French state-owned B.R.G.M., (Bureau de Recherches Geologiques et Minieres). This will augment and increase the value of other deposits previously owned by B.R.G.M. Cofremmi was formerly controlled by the Patino interests, Pechiney and SLN. Patino had spent $18 million on the Cofremmi project by December, 1974.

In New Caledonia, B.R.G.M.-controlled Cofremmi owns:

1) the *Tiebaghi* deposit (garnierite) - open pit; 13 million tons averaging 3 per cent nickel (plus cobalt) proven, plus 17 million tons 1 per cent Ni (plus Co) in laterite.

2) the *Poum* deposit (garnierite); 35 million tons proven, 2.3 per cent Ni plus Co., (plus 41 million tons 1.34 per cent Ni plus Co in laterite). B.R.G.M.-controlled Cofremmi had intended to develop the Poum deposit in a 30,000 to 40,000 metric tons of nickel (in ferro-nickel) per year venture. The project would have cost *2 billion francs*.

Northern New Caledonia — Tiebaghi

Extreme North — deposits of 13 million tons 3% Ni and 35 million tons 2.3% Ni.

It was reported that *AMAX Inc.*, Greenwich, Conn., U.S.A., signed a pact with B.R.G.M. in November, 1977. It will take a 49 per cent stake in the capital funding of a fully integrated New Caledonian nickel project and is negotiating with the French Government.

The balance of 51% will probably be held by French interests, including 21% to be held by the state-controlled Bureau de Recherches Geologiques et Minieres (BRGM). The fully integrated venture involves the exploitation of deposits in *Tiebaghi* in the northern part of the island, with an initial annual production of 26,000 tons of nickel content by 1986 and the possibility of raising output to 34,000 tons. Mining rate: about 1 million tons a year.

This is reportedly *one of the last high grade nickel opportunities left in the Western World*. Ore reserves are estimated at 55 million tons.

The mining rights to the nickel deposits are now 90% held by BRGM. The garnierite ore may run about 2.5 per cent nickel. 10 million tons may be ore with a nickel content close to 3 per cent.

The *U.S. $600 million* project has been under consideration for the past seven years or so. The main trouble has been the struggle between BRGM, Cofremmi and AMAX for the majority stake in the project, resulting in the French claiming the lion's share and AMAX accepting a minor role.

AMAX's investment in the project may run as high as $450 million or $500 million. Commercial output could not be expected before 1985 or 1986.

This will give AMAX an even larger share in New Caledonia's nickel resources. It already had an interest through its 50% holding in *Penamax*, a New Caledonian company set up some years ago with Imetal's subsidiary Penarroya, the SLN affiliate. In 1975, Penarroya sold its interest in Penamax to SLN. AMAX Inc., U.S.A., and Penarroya of France were to have developed a deposit at *Goro* (see below) to produce 25,000 tons of nickel a year, for refining at the new AMAX refinery at Port Nickel, Louisiana, U.S.A. The Cofremmi decision will mean a significant relaxation of the French government's previous policy of only allowing a minimum of foreign participation in the development of New Caledonian nickel.

Southern New Caledonia

Near *Goro*, extreme South, 150 million tons with 1.6% Ni.

A proposal submitted in 1973 by *INCO of Canada* for mining a low-grade lateritic ore body near *Goro* on the island's southernmost extremity has not been acted upon by the French government. If approved, INCO had hoped to produce approximately *20,000 tons per year of nickel* and 1,400 tons per year of cobalt by 1978, at an estimated capital investment of *$275 million*. The company planned to more than double the output of nickel to 45,000 tons of nickel per year at a later date. The project was dependent upon INCO acquiring mining rights to the Goro deposits held by the French Bureau de Recherches Geologiques et Minieres (BRGM).

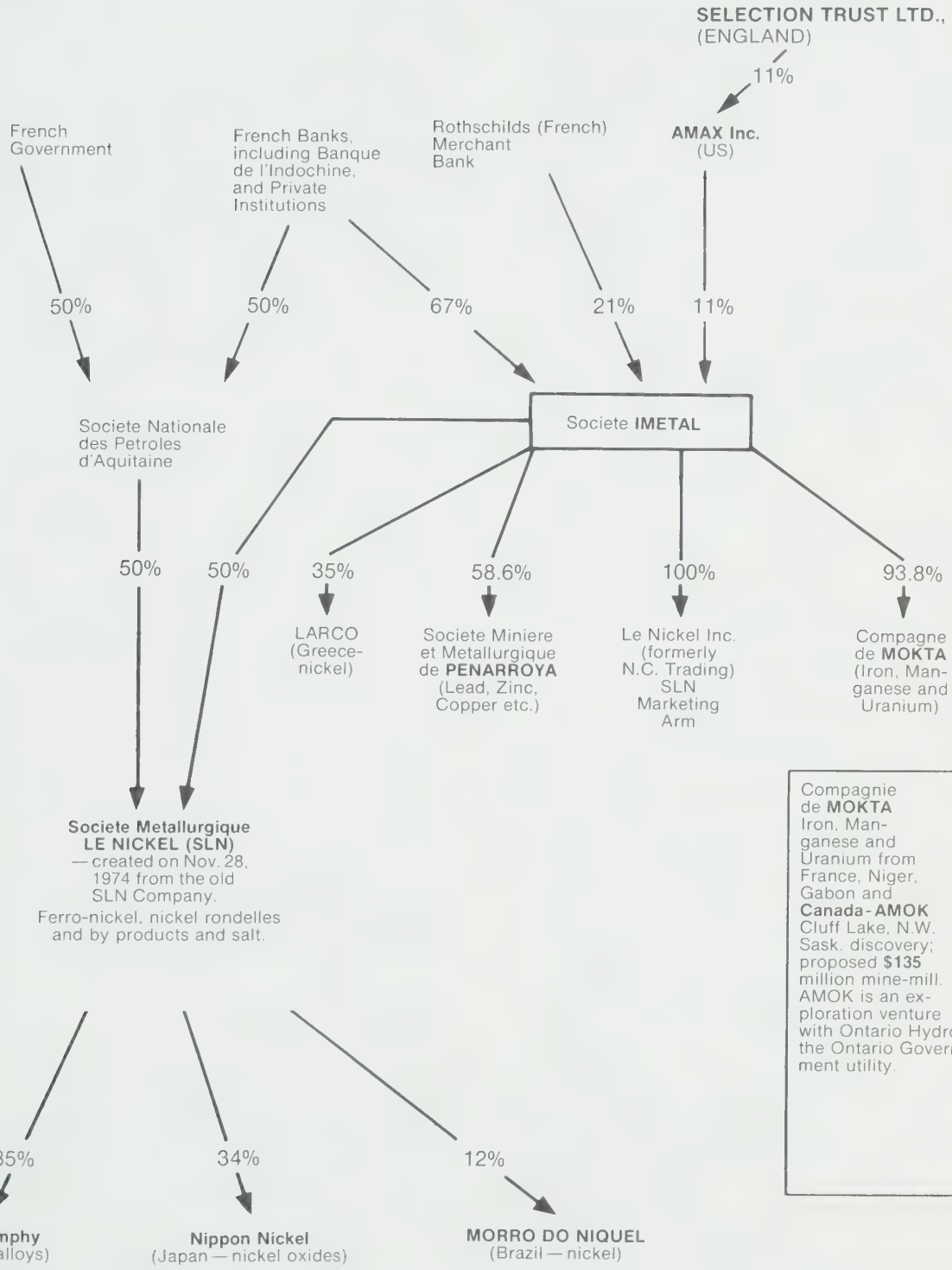
INCO Ltd. of Canada was reported in July, 1977, to have reached agreement with the French Government on the terms on which INCO would carry out further research work on low-grade lateritic nickel deposits in the south of New Caledonia. Under the terms of the agreement, INCO will undertake a large-scale programme of geological, mining and metallurgical studies, and must inform the French Government before *June 30, 1982*, whether it plans to build a commercial processing plant.

COFIMPAC

Agreements, approved by the French Government, in March, 1969, were signed between *Inco* and Societe Auxiliaire Miniere du Pacifique ("Samipac"), a consortium of French public and private interests. A new French company was thus established, Compagnie Francaise Industrielle et Miniere du Pacifique ("Cofimpac"), to develop nickel deposits in the French Pacific island of New Caledonia. Under the agreement, Inco held a 40% equity interest in Cofimpac and would be obliged to provide or arrange for 61% of the total investment, would be obliged to provide for the disposal of 50% of the nickel production capacity and would be entitled to 50% of the profits. As technical adviser to Cofimpac, *Inco* presented a feasibility study to its French partners in July 1970 which outlined a totally integrated project for producing 45,000 metric tons of carbonyl nickel pellets a year for 40 years, utilizing the Inco Carbonyl process for laterites. This initial Cofimpac project was expected to require an investment in excess of $500 million to cover the cost of mining and processing as well as power-generating facilities, a new town and port facilities, working capital and interest during construction. Although the study was favourably received, a number of important matters remained to be settled including the final composition of the consortium. Pre-engineering studies were conducted to permit a rapid start of construction once it was decided to go ahead with the project. The project was to go on stream four years after the decision to proceed is taken. At March 31, 1971 Inco's expenditure on the project amounted to approximately $18 million.

OWNERSHIP OF SOCIETE le NICKEL

(and associated companies)



Compagnie de **MOKTA** Iron, Manganese and Uranium from France, Niger, Gabon and **Canada-AMOK** Cluff Lake, N.W. Sask. discovery; proposed **$135** million mine-mill. AMOK is an exploration venture with Ontario Hydro, the Ontario Government utility.

3.23 Australia

Australia is now the fourth largest mine source of nickel in the world. Australia had no major mine output of nickel before 1967. Western Mining discovered nickel in 1966. There had been a small output in Tasmania years ago. Considerable exploration programs continue. All mines are underground except Greenvale.

Reserves

Australia is reputed to have the seventh largest reserves of nickel in the world.

Australia shares with the Soviet Union the unusual feature of having producing sulphide deposits in one part of the country and laterite production (Greenvale) in another part.

All nickel mines are in the State of Western Australia, except Greenvale in Queensland.

1976 mine production reached a record 75,400 metric tons of nickel contained.

1976 refinery production in Australia was 46,000 metric tons of nickel, (36,300 tons in 1975).

Mine Output of Nickel (metric tons)

1967	1968	1969	1970	1971
2,600	4,700	11,200	29,800	35,500
1972	1973	1974	1975	1976
35,500	40,100	46,000	67,000	75,400

Australian production was **increased** rather than seriously cut back during the recession years 1975 and 1976, but *Western Mining reduced mine output by 10% in 1977.*

a) *Western Mining Corporation Ltd* (an affiliate of Selection Trust Ltd., England)

— operates or manages several sulphide mines; recently took over Great Boulder Mines.

— Mining of nickel began in 1967.

— Its six Kambalda deposits, output capacity 45,000 tons nickel a year, and the 50 per cent owned *Windarra* 14,000 tons nickel p.a. mine project account for over half of the Australian nickel output. The Anglo-Dutch Shell Group will take up the 50 per cent share of Windarra formerly held by Poseidon Ltd., but Shell's share of the output is committed to *Sherritt Gordon of Canada* until 1979 at free market prices.

— The other mines in Western Australia that Western Mining services are Scotia, Nepean, Redross and Spargoville.

— Has a smelter, (Outokumpu of Finland type), at Kalgoorlie — opened in 1972. To be expanded to *72,000 metric tons of nickel a year* (from 35,000 tons). By 1979, the new flash furnace will have a capacity of 450,000 metric tons of concentrates, with plans to reach *1 million tons a year.*

— Has a refinery which opened in 1970, at Kwinana, on the Indian Ocean coast, using the *Sherritt Gordon of Canada* ammonia leach process.

Capacity: now 30,000 metric tons nickel a year; product briquettes and powder.

— Western Mining has exported excess nickel matte and concentrate to Japan.

b) Mine at *Greenvale, Queensland*, (laterite), Queensland Nickel Pty. Ltd.

— Metals Exploration N.L. and Freeport Minerals, U.S.A., are the owners.

— Mine 140 miles inland from the refinery at Yabulu and the port of Townsville, Queensland. The Queensland government made a $50 million 20 year guarantee against the cost of the railroad and has guaranteed the project's debts through 1985. Financial losses continue.

— Total Project Cost: *over $300 million.* Plans to spend $16 million Australian on a major capital expansion program were abandoned in October, 1977

— Commenced operations late in 1974, but officially operative in 1976.

— $160 million refinery at Yabulu, 15 miles North of Townsville on the Northern Queensland Pacific coast; capacity: about *24,000 metric tons of nickel*, (21,000 tons nickel in 90 per cent nickel oxide sinter and 3,000 tons in nickel cobalt sulphides). Nickel-cobalt mixed sulphides started to go to Nippon Mining, Japan in 1976.

- Ore reserves: 40 million metric tons averaging 1.57% nickel and 0.12% cobalt.

c) *Agnew* sulphide mine — Western Australia, 650 kilometres NE of Perth

— Owned by Western Selcast Pty Ltd., (British company Selection Trust Ltd.) 60 per cent and by MIM (Mt. Isa Mines) Holdings Ltd. of Australia, 40 per cent. Asarco, U.S.A. has a 49 per cent holding in Mount Isa Mines. (Selcast are also involved in the Spargoville mine).

— Reserves: one of the world's largest undeveloped nickel orebodies, 40 million tons averaging 2.2 per cent proven nickel. Could be the country's third largest nickel producer.

— *$100 million project.* The government of Western Australia guaranteed a $10 million loan to this project, which involves construction of mine, smelter and town.

— Production could start by late 1978 or early 1979.

— AMAX Nickel, Inc., U.S.A., announced in July, 1977, the signing of contracts for the purchase of the total production of the Western Australia "Agnew" nickel project, up to an *annual maximum* of *15,000 metric tons of nickel* contained in concentrates. An output of 10,000 tons a year by 1979 is projected at the moment.

The contracts were valued at approximately *U.S. $500 million.* Agnew's output will be custom smelted at Western Mining Corporation's Kalgoorlie smelter and the resulting matte shipped via the port of Esperance, Australia, to the AMAX Nickel plant at Port Nickel, Louisiana, U.S.A. for further refining.

d) *Spargoville mine*

— Selcast is the sole owner.

nickel-copper mine; 4,000 tons nickel per annum.

nickel output at Spargoville was 2,400 tons in 1976-77, 43 per cent above 1975-76.

e) *North Kalgurli Mines Ltd. Croesus Mill*

— Concentrated the ore from the Spargoville and Redross mines which went to the *Sherritt Gordon* nickel refinery at *Fort Saskatchewan*, Alberta, Canada.

f) *Redross mine* — Anaconda/AM&S/Con. Tio Tinto

— Half of the matte from the Redross mine at Widgiemooltha, West Australia also went to *Sherritt in Canada*. 4,000 tons nickel per annum.

g) Wingellina mine project (BHP) — had a plan for a 1977 start up.

h) *Nepean underground mine* — Freeport Minerals/Metals Exploration (which also has an interest in Greenvale). 3,000 tons nickel per annum.

i) *Great Boulder Mines*, (now a wholly owned subsidiary of Western Mining) owns:

— *Scotia* underground mine — 2 per cent nickel; 3,000 tons nickel per annum; and

— *Carr Boyd* Rocks mine — closed in June, 1975.

j) *Mt. Keith* nickel project — Freeport Minerals/Australian Consolidated Minerals/Metals Exploration, 1/3, 1/2, 1/6 respectively.

– 0.6% Ni.

NICKEL CONSUMPTION, AUSTRALIA (estimated)
(metric tons)

1972	1973	1974	1975	1976
3,600	5,000	4,800	2,000	4,000

3.24 Indonesia

INDONESIA HOPES TO BE THE WESTERN WORLD'S THIRD LARGEST MINE PRODUCER OF NICKEL BY THE 1980's.

INDONESIA SHOULD *REPLACE CANADA* IN THE NEAR FUTURE AS THE MAIN SUPPLIER OF MATTE TO JAPAN AND SHOULD BECOME A STRONG SUPPLIER OF FERRO-NICKEL.

NICKEL RESERVES — LATERITES — INDONESIA

Reserves assumed to be 8 million tons nickel proven. The Indonesian government believes that there are sufficient nickel reserves for 100 years, at current production capacity.

Mine Output of Nickel (metric tons)

1967	1968	1969	1970	1971
3,800	5,500	4,900	10,800	14,700
1972	1973	1974	1975	1976
14,100	15,800	16,000	14,600	13,800

Indonesia produced more than 828,000 metric tons of nickel ore in 1976, up 3.5 per cent from 1975.

MINES AND PROJECTS

1) **"PT INCO-Indonesia": (INCO Ltd. of Canada has control)**

Stage I came *onstream in Spring, 1977*. Debugging delays meant less 1977 production than planned. 16,000 metric tons of nickel per annum planned. Production will be held to levels substantially below those previously planned *for 1978* and employment levels will be lower.

Stage II — 45,000 tons of nickel per annum by 1980 — with a 165 MW hydroelectric plant on the Larona river, which will commence supplying power during the first quarter of 1978. INCO estimates that in the first 10 years of operation the grade of ore mined will vary between 2.4% and 2.1% nickel. They state that the second stage of expansion will be "physically completed by mid-1978 and *commissioning of the stage is scheduled to follow.*" Japan may be unable to accept all of the nickel originally contemplated.

Stage III — no details.

Plant Cost: *$875 million,* when completed, (including the hydroelectric power plant). The availability of hydroelectric power is a great cost advantage, compared to New Caledonia for example. Dravo and Bechtel are the contractors. As of September 30, 1977, $693 million had been invested in the project. Since the project is being financed by 1/3 equity and 2/3 long-term debt, INCO had contributed $226.75 million to INCO-Indonesia's equity. Six Japanese corporations had purchased an aggregate of $11.25 million of INCO-Indonesia's equity capital. The long-term debt financing for the project is being provided by three international syndicates of commercial banks and through government agencies in the U.S.A., Canada, Japan, and several European countries. Therefore, the capital cost per pound of nickel produced, assuming 45,000 metric tons of nickel capacity, is now estimated at $8.93 per pound (our estimates). It is interesting to note that INCO has not extended a financial guarantee of the debt of INCO-Indonesia.

Loans:

1) The Government of Canada's Export Development Corporation is reported to have made available low-interest loans totalling some $70 million to INCO's nickel-mining subsidiaries in *Guatemala, Indonesia* and *New Caledonia*.

The Chairman, John MacDonald is reported to have said that E.D.C. loaned INCO $20.75 million for Guatemala and $57.25 million for Indonesia in order to get equipment orders for Canadian suppliers. The allegation had been made that the E.D.C. had effectively been exporting jobs from Canada.

2) U.S. Export-Import Bank loaned U.S. $13.5 million and guaranteed a similar loan from the *Bank of Montreal*.

n.b. Strict loan repayment schedules for these expensive overseas ventures, (*Indonesia* and Guatemala — total cost to INCO: *over $1 billion*), will put INCO under severe pressure to sell the Indonesian and Guatemalan output as priority over the Canadian (Ontario and Manitoba) nickel. INCO started to cut back Ontario mine and refinery output and reduce employment in 1977.

Employees: 3,000 will be employed eventually.

Sumitomo says that INCO's shipments from Soroako to Japan, are *to replace nickel oxide/matte from INCO in Canada.* This situation is not yet clear.

A proportion of (formerly all) foreign exchange earnings have to be repatriated to Indonesia.

Reserves: Soroako, 250 million tons ore, 1.76% Ni.

Mine is at *Soroako*, served by the port of Malili, on Central Sulawesi Island, (formerly Celebes).

Smelter Capacity: Currently 16,000 metric tons of nickel contained per year.

Product: 75% Nickel Matte — "Can serve as feed to any of INCO's refineries in Canada and U.K." — Mr. E. Carter, President of INCO. However, *50% of output is to go as matte to the Japanese market for 15 years* and the rest to INCO's U.K. refinery at Clydach, Wales, which is being expanded at a cost of *U.S. $13.8 million* for a new fluid-bed roasting plant and sulphuric acid plant, which has a completion date of December 1978.

2) **ANEKA:** The only nickel producer in Indonesia through 1975. 4,000 to 4,250 metric tons of nickel contained in 20,000 tons of ferro-nickel, all for Japan. With ore exports, about 17,000 tons of nickel p.a.

The State-owned Indonesian Mining Corporation, P.T. Aneka Tambang (ANEKA), has a mine near Kendari, South Sulawesi and a smelter at *Pomalaa* South, East Sulawesi Island, designed to produce 4,000 tons of nickel in ferro-nickel per year. The ferro-nickel plant at Pomalaa came on stream early in 1977. Japan was to import the entire output of ferro-nickel and ore. ANEKA's nickel ore shipments to Japan were averaging 2.4 per cent nickel content. Philipp Brothers Division of Engelhard, New York, is obtaining 100,000 metric tons of ore, 2.5 per cent nickel content, from Aneka, which Nippon Mining, Japan, will refine from late 1977.

Indonesia has commenced an exploration program in the *Pomalaa* area to assist in meeting a 10-year contract of 10 million tons of nickel exports to Japan.

Hunt for the Nickel Ship

POMALAA WAS JAPAN'S SOLE SOURCE OF NICKEL DURING WORLD WAR II. An attempt was made to sink the "nickel ship", (which left Japanese-held Pomalaa in the Gulf of Boni, Celebes, Dutch West Indies — now Bone, Sulawesi, Indonesia — about once a month), by the U.S. submarine Harder, commanded by Congressional Medal of Honor winner, S. D. Dealey, but this failed.

Pomalaa is about 100 miles SE of INCO's new nickel mine at Soroako.

3) **Gag Island, PT Pacific Nikkel Indonesia**

In November, 1977, Amoco Minerals Co., subsidiary of Standard Oil of Indiana, joined a consortium that will develop a *U.S. $1 billion* nickel project in Indonesia. Amoco's partners in the venture: *United States Steel Corp.* and Hoogovens N.V. of Holland, steelmakers. Financing may be a problem.

Pacific Nikkel have asked the government for a 2-year extension of the time by which it must make a decision on whether to proceed. Development was to start in 1979 with completion of the project in 1983-84, with a production capacity of 51,000 metric tons of nickel a year.

A large laterite deposit of unusually high grade, (about 190 million tons averaging 1.4% Ni, 0.15% Co), has been studied by Hoogovens and U.S. Steel corporation for many years. It is located on Gag Island off the Northwest coast of Irian Jaya, (formerly Dutch New Guinea), West of the Wigeo area and the Sentani Islands. It is organized as the *P.T. Pacific Nikkel Indonesia* company.

That company planned to produce *45,000 metric tons of nickel* and 1,800 tons of cobalt per year. By end 1973, pilot plant testing of the ore had been completed, and feasibility studies were being made by *Sherritt Gordon of Canada.*

In 1976, it was in the evaluation state. Companies involved in this venture: the United States Steel corporation, Newmont Mining Corp., (Sherritt's parent) and Koninklijke Nederlandsche Hoogovens en Staalfabrieken, N.V. *Sherritt* held 9 per cent, Newmont 16.7%, U.S. Steel 47.8%. Newmont withdrew in May, 1977; Sherritt earlier. However, *Sherritt's refining process* will be used.

The government of Indonesia said in 1977 that it would participate in the Pacific Nikkel development. A 20 per cent equity stake has been taken up and the government has agreed to contribute 35 per cent of total investment cost.

4) **Obi and Gebe Islands**

On Obi and Gebe Islands, (Halmahera group), so far 60 million tons 1.6-2.2% Ni. Total reserves estimated 4.5 million tons of contained Ni.

Gebe Island lies right on the Equator — 32 million tons of ore averaging 2.22 per cent Ni.

Indonesian Nickel Development Ltd. (Indeco)
— nickel mining project in Irian Jaya. Less feasible than Pacific Nikkel.

A Japanese consortium of nickel refinery companies, including Sumitomo Metal Mining, Nippon Steel and Mitsubishi Shoji, decided in August, 1977 to shelve plans to develop nickel and ferro-nickel and build a *$500 million* ferro-nickel smelter at Gebe Island in the Indonesian Halmahera Group. The decision was taken because depressed prices and the current gloomy outlook for nickel mean that the mine would not have been as profitable as was once thought possible.

The scheme dates back to 1969 and was slated to produce 26,000 tons of nickel a year by 1980. However, the capital cost gradually rose until it reached some *2.5 billion yen* and, with the energy crisis pushing development costs sky high, the decision to drop the project was inevitable.

NEW MINES POLICY

The Indonesian Government sincerely wants to increase foreign investment in resource production. The Indonesian Department of Mining announced in October, 1976 the basic provisions of its so-called "third generation" mining contracts. Twenty applications for mining investments in tin and nickel and copper-rich Indonesia have been awaiting the new government regulations.

While contractual details were yet to be finalized, the government cited four provisions of the new stipulations.

1) Company *taxes* will be at *35%* for the first 10 years of mining production and *45%* for the next 20 years, or until contract expiration.

2) All material imported by a contractor will be *tax-free* during the first *10 years* of production.

3) As an investment incentive, the government will allow a 20% cost recovery over the first four years (5% per year).

4) Writeoffs of 10-12.5% per year will be permitted so that "investors will be able to recover costs as quickly as possible".

One regulation which was absent from the government announcement in 1976 was a requirement that investors set aside a percentage of the profits for reinvestment.

Model Agreement (Third Generation)

In June, 1977, Indonesia and Rio Tinto-Zinc Corp. signed a mining contract that the Indonesian government hopes will attract more foreign mining investments.

The agreement is expected to serve as a model for future non-oil mineral pacts with Indonesia, except for coal and uranium, which will be under special arrangements. The contract is the first settled under Indonesia's so-called third generation mineral exploration and production contract terms.

The 30-year contract is *the first* non-oil mineral accord Indonesia has reached with a foreign mining company *since 1972*. The terms give P.T. Rio Tinto Indonesia – a joint venture company owned by Rio Tinto-Zinc Corp. of Britain and Conzinc Rio Tinto of Australia Ltd. – exploration and production rights for copper and other base metals on a 6,500-square-mile concession in northwest Sulawesi.

Indonesian officials have been working on prototypes of third generation mining contracts for nearly five years in an effort to come up with terms more favourable to the country. As previously reported, the contract reflects these efforts in several areas:

1) A 10% tax will be levied on exports of *unprocessed minerals*. Under first and second generation contracts, an export tax wasn't levied.

2) A windfall-profit tax of 60% will be levied on Rio Tinto when average *returns on investment* exceed 15% over a three-year period. An allowance for such a tax didn't exist in previous mining contracts.

3) Rio Tinto and Conzinc must offer at least 51% of their shares in P.T. Rio Tinto Indonesia to Indonesian nationals within 10 years of beginning mineral production. (Under second generation contracts, foreign companies had to offer to divest themselves of up to 25% of their shares within 10 years of starting production.)

4) Terms also specify that *foreign exchange revenue* generated from future mineral production may be held offshore but in special overseas accounts designated by Indonesia's central bank. Although the foreign company won't be required physically to repatriate its revenue, the central bank will approve the use of the offshore foreign exchange holdings and will require that monies to be used abroad *first* be converted to rupiah and then back to foreign currency. The central bank will collect a commission on the exchange.

   Under previous mining contracts, the companies could use foreign exchange revenue *as they wished* after repatriating any required payment to Indonesia.

3.25 Philippines

LATERITES

Mine Output of Nickel
(metric tons)

1971	1972	1973	1974	1975	1976	1977
200	384	400	326	10,263*	18,803*	19,442* est.

*Philippines Bureau of Mines.

1) **MARINDUQUE MINING AND INDUSTRIAL CORPORATION**

U.S. $295 million nickel project.

Sherritt Gordon of Canada has an 11 per cent interest in the "Marinduque" mine.

Open pit mine at Surigao, Nonoc Island in Mindanao, came on stream late in 1974; 1.2 per cent nickel. Cut-off grade raised to 1 per cent in 1976. A hydroelectric plant is planned, costing about *$250 million*, but financing is difficult.

Rated Annual Capacity: 31,000 tons of pure nickel a year, plus 3,000 tons of nickel and 1,500 tons of cobalt a year in nickel-cobalt sulphide. 90 per cent of rated annual capacity to be reached in early 1978.

Output: Production rate at the end of 1977 was about two-thirds of rated capacity. 14,261 metric tons of nickel in 1976, plus 922 tons in sulphides.

Sherritt Gordon of Canada's ammonium carbonate leach hydrometallurgical refining process is used under licence.

The Nonoc nickel refinery of Marinduque, which started production in 1975, is the largest pure nickel producer in Southeast Asia. It reached an average 45 per cent of design capacity in 1976.

This was among the first commercially refined nickel metal to be produced from lateritic ores in the world in regular production, by the ammonium carbonate leach process. Briquettes and powder are the forms. Mixed sulphide concentrates are also produced, formerly sold to *Sherritt Gordon of Canada*, but now all to Japan.

The company also produces copper concentrates and manufactures cement.

SALES ARE HANDLED BY THE AGGRESSIVE AND SUCCESSFUL PHILIPP BROTHERS DIVISION OF ENGELHARD MINERALS AND CHEMICALS CORPORATION, NEW YORK, U.S.A., EXCEPT FOR JAPAN.

2) **RIO TUBA NICKEL MINING CORPORATION, Southern end of Pulawan Island, Philippines**
(40% owned by *Pacific Metals Co.* of Japan)

- At least 350,000 tons of ore were scheduled for 1977 and 500,000 tons of wet ore containing about *8,300 tons of nickel* for 1978.
- Could produce 10,000 tons of nickel a year in garnierite ore (500,000 tons).

  A new source of nickel for Japan. It is all to go to Japan under a 10-year contract.

Ore Reserves: 30 million tons averaging 2.2 per cent nickel.

3) **Acoje Mining Company**, Makari, Santa Cruz, Zambales Province, N.W. of Manila. The country's first nickel producer, at about 300 tons nickel per annum, through 1975; capacity 1,000 tons nickel.

4) **Falconbridge Nickel Mines of Canada** were looking into deposits in Zambales Province held under option in 1976.

5) **ATLAS**
Atlas Consolidated Mining and Development, deposits on Pulawan Island and in Davao, Southern Mindanao.

Ore reserves 1.73 million metric tons, 1.55 per cent Cu and 1.02 million tons 0.42 per cent nickel.

Could produce 17,000 metric tons of nickel a year.

6) **Olympic Mines**

Laterite ore at Pulot and *Toronto* on Pulawan.

NICKEL CONSUMPTION — PHILIPPINES

The Philippines consumes about 1,900 metric tons of nickel a year.

3.26 China — Mine Production of Nickel

In 1973 and 1974, (the latest years available), China is estimated to have produced about 4,500 metric tons of nickel a year in electrolytic cathode form. Source of this ore is not known.

NICKEL IMPORTS INTO THE PEOPLE'S REPUBLIC OF CHINA

Nickel metal, including alloys, all forms

Total Exports to China	Principal sources	
Metric Tons		Metric Tons
1970		
4,156		
1971		
3,077		
	Netherlands	1,261
	France	1,104
	Canada	250
	Sub Total	2,615
1972	Canada	5,614
7,775	Norway	1,010
	Sub Total	6,624
1973 [1]		
23,302	Mainly from Canada	

(1) Quantity reported excludes imports from Japan valued at $91,000.

Source: U.S. Minerals Yearbook 1972, 1973 and 1974.

3.27 India

Sukhinda deposit, Orissa State; Ore reserves said to be 65 to 78 million tons averaging 0.85% nickel; Hindustan Copper Ltd.

Project announced in 1972 deferred to 1980, under the 6th Five Year Plan. Foreign consultants will be employed.

Could be in production after 1980 at about 4,800 to 5,000 metric tons of nickel powder a year, and 200 tons of cobalt a year (in 500,000 tons of ore per year). Cost estimated as *400 million rupees.*

CONSUMPTION

India consumes about 2,500 metric tons of nickel a year, all of which is imported at the moment, (mainly from Canada).

3.28 Europe — Albania and Czechoslovakia

ALBANIA

Reserves: Ore is similar to Cuba's laterites 0.5% Ni, 0.06% Co; only Fe concentrates apparently processed so far. Equipment for producing 28-40% Ni concentrates to be delivered by Red China. Occurrences near Bushtrice, Pishkash, Prenjas, Pogradec, Guri Pergjegjui and Cervenake.
(Met. Bulletin, 15.5.70 pp. 27,31).

Mines near Kukes, Pogradec and Korca. Nickel (in iron-nickel) mine output should increase by 260 per cent in the future from the highly mechanized mines at Prenjas and Guri i kuq now being sunk. Chinese aid is reported.

Mine Output of Nickel (metric tons)

1971	1972	1973	1974	1975	1976
6,000	6,000	5,800	5,600	6,500	7,000

Mine production, 1974, 400,000 tons of iron-nickel ore.

A new concentrator in the Pogradec area to treat nickel ore is now in production and will supply feed to the Elbasan metallurgical complex.

The new (1976) Elbasan steelworks will require much of Albania's nickel output, it is reported.

CZECHOSLOVAKIA

Mining of nickel ores at Josove in East Slovakia is planned for 1985-90.

SERED, SLOVAKIA

SERED NICKEL WORKS

The Sered refinery, a few miles NE of Bratislava, (formerly Pressburg), has produced up to 3,000 tons of refined nickel metal a year from imported Albanian ore from a mine near Tirana. It is not clear whether some Cuban nickel concentrates are treated. The process used at Sered is ammonia leaching with natural gas as fuel.

Nickel, Primary Metal, Output — Czechoslovakia (metric tons)

1972	1973	1974	1975	1976
3,000	3,000	3,500	3,500	3,500

Nickel Consumption — Czechoslovakia (metric tons)

1972	1973	1974	1975	1976
6,000	7,000	7,000	8,000	8,000

Czechoslovakia ranks as the second largest consumer of nickel in the Comecon countries, after the Soviet Union.

3.29 Europe — Finland

SULPHIDE DEPOSITS

OUTOKUMPU OY (State-Controlled Company), Harjavalta

Plant: *Harjavalta:* Copper and nickel flash smelters; electrolytic nickel plant, atmospheric leaching of high grade nickel matte and nickel electrowinning.

Pori: Copper electrolysis plant: precious metals refining plant; nickel and copper salt plant; copper, brass and special alloy foundries; rolling mill; drawing mill; tube mill; wire mill.

Products:	Capacity (metric tons)
Cathode nickel	12,000
Nickel sulphate output	860

KOTALAHTI nickel-copper mine (started 1959) now the largest nickel producing mine in Finland. Approaching exhaustion.

KYLMAKOSKI nickel-copper mine

HITURA — complex ore deposit — uneconomical.

VUONOS

Nickel ore *output* was *stopped* at the large Vuonos open pit and underground mine, (lowest nickel grade in the world, 0.15% Ni), in mid-1977, owing to impaired productivity. It came on stream in 1972, after discovery in 1965.

Nickel Mine Output, Finland (metric tons)

Nickel in concentrates

1972	1973	1974	1975	1976
5,200	5,800	6,000	5,700	6,400

TOTAL NICKEL METAL PRODUCTION, FINLAND

(metric tons cathode nickel)

1972	1973	1974	1975	1976
5,500	5,800	6,500	6,500	7,600

Outokumpu Nickel Refining Process

hydrometallurgy and electrowinning, to produce nickel cathodes

1973 refining capacity: 11,000 metric tons per year of electrolytic nickel

1973 smelter capacity: much lower, at something over 6,000 tons nickel contained.

Nickel Consumption — Finland

- about 500 tons of nickel a year.

3.30 Europe — East Germany

ST. EGIDIEN, GLAUCHAU, (SAXONY)

Total electrolytic refining capacity is 3,000 metric tons nickel contained per year.

Mine Production of Nickel — East Germany (metric tons)

1972	1973	1974	1975	1976
1,900	2,000	2,200	2,400	2,500

EUROPE — WEST GERMANY

No nickel deposits, but has important small nickel refineries using imported ores and concentrates.

Badische Anilin (Badilin)

Norddeutsche Affinerie

Borchers, Goslar.

3.31 Europe — Greece

LATERITE DEPOSITS

120 million tons 2.5% Ni near Koris; lesser deposits near Lokris (1.4% Ni). *Skalistiris*-Kakavos open pit mine on Euboea, 50-meter thick lateritic deposits 1-1.3% Ni; half billion tons reserves; processed to ferro-nickel with 24-33% Ni.

1) *LARCO* Company, (Societe Miniere et Metallurgique de Larymna S.A.) Larymna, (71 miles NE of Athens). It is believed that the French Imetal Group, which controls Ste. Metallurgique Le Nickel — SLN, holds about 70 per cent of the Greek holding company, which is equivalent to 35 per cent of LARCO.

The Belgian company, Societe Generale des Minerais, has been exclusive sales agent for the ferro-nickel output. The Swedish alloy steel industry has been the largest customer.

Expansion

- *First Stage* scheduled to be completed by December, 1978, (from 16,000 to between *20,000 and 27,000 metric tons of nickel a year,* in ferro-nickel. Krupp plants have received orders totalling DM25 million for a 3600 tpd shaft rotary furnace, a 50MVA electric reduction furnace and two oxygen blast converters.
- *Second Stage* (no target date known) (to *40,000 metric tons of nickel a year*).

Two groups of mines:

A. 80% of total ore comes from the new Euboean area (open pit), at Skalistiris-Kakavos, near Politika, 1.1% nickel, *virtually arsenic free.* Production commenced in 1969.

B. 20% of total ore comes from the old Aghios Ioannis mine, near Larymna, (underground), 1 to 1.6% nickel with arsenic content; may be converted to open pit.

Total Reserves: 240 million tons est.

2) Intercontinental Mining and Abrasives, Inc. and Southland Mining Co. were considering a nickel refinery near Lake Ionina. The refinery, estimated cost $30 million, was to produce 12 million pounds of ferro-nickel per year. The project was to have been completed by 1974.

OUTPUT OF NICKELIFEROUS ORES — GREECE
(metric tons)

1975	1976	1977
1,974,425	2,204,860	2,400,000 estimated

TOTAL FERRO-NICKEL PRODUCTION AT LARYMNA
metric tons nickel plus cobalt content of ferro-nickel (24-26% Ni plus Co)

1970	8,600
1971	10,600
1972	11,300
1973	13,900
1974	15,100
1975	14,827
1976	16,400
1977 (est.)	16,000

Some Greek ferro-nickel was imported and used in Canada during 1977.

3.32 Europe — Poland

Small lateritic deposits at Zabkowice (Frankenstein) and Szklary (Glasendorf) accounted for 1,500 to 2,000 tons per annum, 1970-1974.

Mine Output of Nickel
1976 mine output of 192,100 metric tons of nickel ore, (nickel content unknown), was 12.4 per cent above 1975.

(metric tons — nickel content of ore)

1971	1972	1973	1974	1975	1976
1,500	1,500	2,000	2,200	2,500	2,800

Nickel Consumption (metric tons)

1971	1972	1973	1974	1975	1976
N.A.	5,000	5,000	7,000	7,500	7,800

Poland ranks as the third largest consumer of nickel in the Comecon countries of Eastern Europe, after the Soviet Union and Czechoslovakia, which is close to Poland's level.

3.33 Europe — Yugoslavia

1) Lateritic deposit at *RZANOVO-KAVADARCI* in South Macedonia, 20 miles from the border with Greece. 24 million tons averaging 0.9 per cent nickel. Also 110 million tons 31-33% Fe, 1% Ni, 2.03% Cr_2O_3 and some Co rated as metallurgically very difficult.

   Similar deposits discovered near Pristina (25 million tons).

   NEW "FENI" COMPLEX — FERRO-NICKEL MINE AND SMELTING PROJECT (FENI NICKEL, STEEL & ANTIMONY MINES & INDUSTRY, a government unit) — to come on stream in September, 1979.

   WILL BE THE LARGEST METALLURGICAL PROJECT IN EUROPE WITH ITS OWN RAW MATERIAL SOURCE, (excluding the U.S.S.R.).

   COST: *U.S. $170 million* (mostly from American banks). The U.S. Export-Import Bank extended a U.S. $38.7 million credit.

   Arthur G. McKee of Cleveland, U.S.A., is giving technical assistance. The main equipment for a 4,800 tpd nickel ore pelletizing plant at Kavadarci, Macedonia, is to be supplied by the American affiliate of Polysius AG, Neubeckum, of the Krupp group. The order, worth over Dm50m., was obtained through the export-import firm RTB-Bor-Oour Jugotehna from the Yugoslav company Rudnici i Industrija za Nikel. The pelletizing plant will be part of the new *16,500 tons of nickel* contained in 64,000 tpy ferro-nickel complex on stream in 1980. 90 per cent will be for export.

PRODUCTS will be:	Capacity (metric tons)
Ferro-nickel, 25 per cent Ni	16,000 (nickel cont.)
Iron concentrates, 55 per cent Fe	600,000
Antimony metal in concentrate, 55 per cent Sb	2,400

   n.b. 90 per cent of the production will be exported.

2) Goles near Pristina and Cikatovo deposits in Kosovo, Southern Serbia.

   — Could produce from open pit 10,000 metric tons of nickel in ferro-nickel a year.

   — Ore reserves 25 million tons, reported average 1.36 per cent nickel.

   — Soviet specialists have been working on the project. Soviet equipment would be used for the mine, concentrator and smelter.

   — 80 per cent of the financing for this project was to have come from the Soviet Union. Financing is a major problem. The projected 1978 start-up seems unlikely.

Nickel Consumption
Yugoslavia normally consumes about 1,400 metric tons of nickel a year.

3.34 Botswana (formerly Bechuanaland)

Selebi-Pikwe Project — mixed sulphides deposit.
Pikwe: 31 million tons 1.1-1.45% Ni, 1.1% Co;
Selebi: 12.6 million tons 0.7-0.9% Ni, 1.3-1.6% Co.

Botswana R.S.T. Rhodesian Selection Trust has control. The Botswana government has 15 per cent. AMAX Inc., U.S.A. holds 29.8 per cent of Botswana R.S.T.

Open pit and underground mine at Pikwe. Initial open pit mining (Bamangwato Concessions Ltd.) at Pikwe with 46,000 tons per annum of matte containing 18,160 tons nickel and 16,800 tons Co. Delay in achieving full output and positive cash flow continued in 1977.

Mine output commenced at the end of 1973. After several years of startup troubles, Bamangwato Concessions Ltd. of Botswana, announced in July, 1977, that the Outokumpu of Finland type copper-nickel smelter had reached its designed capacity of 3,500 tons of matte per month. The copper-nickel matte is

shipped to the AMAX nickel refinery at Port Nickel, Louisiana, U.S.A. for refining into nickel, copper and cobalt.

$25 million for the power plant was *funded by the Government of Canada.*

The Selebi mine, 9 miles away, may open in 1979.

Mine output of Nickel
(metric tons content of matte)

1973	1974	1975	1976	1977
500	2,600	6,300	12,600	14,000 (or more)

3.35 Rhodesia (also known as Zimbabwe)

SULPHIDES

Mine output of nickel (metric tons)

1973	1974	1975	1976
11,800	11,500	10,000	10,000

Refined nickel produced

1973	1974	1975	1976
10,000	10,000	9,000	10,000

1. Rhodesian Nickel Corporation (Rhonickel)
   - — Trojan, Epoch and Madziwa mines near Bindura, where the smelter and refinery are located. This has been recently expanded to handle the Shangani and Epoch concentrates.
   - Bindura, refinery output should reach 5,000 tons of electrolytic nickel by 1980. Smelter capacity: 11,000 tons of nickel contained.
   - Total mine output: 10,000 tons of nickel a year.
   - Epoch mine in production.
2. Shangani open pit mine at Inyati (start up 1975)
   - — may reduce output or suspend output completely; net loss of $2.4 million for year ended June 30, 1977.
   - — underground development was underway; 4,000 tons nickel p.a. target.
   - — owned by *J.C.I., (Johannesburg Consolidated Investments Co. Ltd.* of South Africa).
   - Reserves 23 million tons at 0.7% Ni.
   - — Ore goes to the Bindura smelter-refinery.
3. Empress & Perseverance Mines
   - Owned and Operated by *Rio Tinto* (Rhodesia) Ltd.; 9,000 tons nickel p.a.
   - Smelter and refinery at Gatooma, capacities: 9,000 tons Ni and 3,500 tons Ni respectively.
4. Hunters Road area, Central Rhodesia — large nickel deposit discovered in 1977.
   - — **Union Corporation**
   - Reserves 60 million tons averaging 1 per cent nickel.
   - — 1978 should see start up.
   - — WOULD DOUBLE RHODESIA'S NICKEL OUTPUT.

N.B. — RHODESIA HAS REPORTEDLY SOLD ALL ITS NICKEL OUTPUT SUCCESSFULLY DURING THE LAST DECADE, IN SPITE OF SANCTIONS BY MANY NATIONS.

3.36 Republic of South Africa

NICKEL RESERVES

South Africa claims to be sixth in world reserves of nickel, in spite of the fact that all nickel output in South Africa is a co-product of the mining of platinum group metals.

Mining

FOR EVERY TON OF THE ELEMENT PLATINUM THAT IS RECOVERED FROM THESE ORES, ANYTHING BETWEEN 350 AND 850 TONS OF NICKEL ARE OBTAINED, DEPENDING ON THE AREA.

Mine Output of Nickel (metric tons)

1967	1968	1969	1970	1971
5,700	7,500	9,000	11,600	12,800

1972	1973	1974	1975	1976
11,700	19,400	22,100	20,800	22,400

n.b. — 14,434 tons of nickel were exported in 1974, 40 per cent above 1973.

Refined Nickel Output (metric tons)

1971	1972	1973	1974	1975	1976
11,000	13,000	15,000	17,000	14,000	17,000

South Africa now refines to primary nickel metal most of its own mine output under the South African government's "further processing policy".

Not too many years ago, ALL of the country's PGM and nickel output went to the U.K. for refining. (n.b. — Ontario's PGM's still do, as does a sizeable proportion of Ontario's nickel output which goes to the U.K. and Norway for refining to metal.)

In 1976, South Africa produced about 18,000 metric tons of "refined" nickel. Some concentrates or matte may still be exported.

PRODUCTION COSTS HAVE BEEN RISING AT A RATE OF OVER 20 PER CENT A YEAR, MAINLY DUE TO WAGE INCREASES.

TAXATION OF MINES

South African tax laws do not allow depreciation of mining assets, because full recovery of capital expenditures is allowed early in the mine life before any tax is paid.

REPUBLIC OF SOUTH AFRICA MINES

	Nickel Output Capacity (metric tons)
Rustenburg Platinum mine (J.C.I.)	10,000 (9,000 ref. capacity)
Atok platinum mine, (Rustenburg Platinum — formerly owned by Anglo-Transvaal 30 per cent and U.S. Steel Corporation 30 per cent)	n.a.
Impala platinum mine (Union Corp.) (*INCO of Canada* has 10 per cent) (chemical refinery at Springs, Tvl.)	10,000 (8,000 ref. capacity)
Western Platinum mine (Lonrho; *Falconbridge of Canada;* Superior Oil, U.S.A.)	3,000 est. in matte
TOTAL — REPUBLIC OF SOUTH AFRICA	22,000 tons nickel a year capacity

Main Sources: U.S. Bureau of Mines; J. Aron & Co.; "Mining Annual Review"; "Guide Minemet 1977" of Imetal.

NICKEL CONSUMPTION

— not known, but is probably around 5,500 metric tons a year.

Rustenburg Platinum Mines Limited

The plan to produce 34 metric tons of platinum group metals by early 1977 was slowed by market weakness.

Rustenburg operates three mines on the Merensky reef and the Atok mine, including the largest underground mine of its type in the world. It is the world's largest single mine producer of the element platinum. 40 per cent of the company's PGM output is palladium; 10 per cent is ruthenium, 5.6 per cent is rhodium and over 1 per cent is iridium.

Rustenburg is controlled by J.C.I., the Johannesburg Consolidated Investment Group. However, Anglo-American and its subsidiary, Engelhard, U.S.A., as well as other groups have indirect minority interests in Rustenburg. The web of company cross-holdings is too complicated to compress into this summary.

Rustenburg are joint owners of a precious metals refinery, Johnson Matthey Refiners (Pty.) Ltd., and a *nickel-copper refinery, (Matte Smelters Pty. Ltd.),* in Germiston, Tvl., South Africa, with Johnson Matthey of London, England, their world selling agents.

Rustenburg produced about 40 metric tons of platinum in 1974, with capacity to reach 47 metric tons a year by the end of 1975 and 50.7 tons by 1978. Any increase in platinum production naturally means a higher output of *nickel*, copper, palladium and other precious metals in the group. Some *nickel-bearing* material was sold to AMAX, U.S.A. for refining in 1976.

Rustenberg states that it delivered more platinum to the U.S. auto industry during the first half of 1976 than it delivered in all of 1975. Rustenburg made a commitment to provide platinum to many auto makers in the U.S. for exhauts catalysts, manufactured by Engelhard, U.S.A., (controlled by Anglo-American Corporation of South Africa), involving a minimum of 15 metric tons of platinum per year of each of the model years, 1975, 1976 and 1977.

Sales of *nickel* and PGM's are made through Johnson Matthey as agent, with part of the Rustenburg refined precious metal output going direct to Engelhard, U.S.A., under long-term sales agreements.

Atok Mine

In the summer of 1977, *Rustenberg* acquired the Atok mine for $2.3 million. Through Atok Investments Co. Ltd., the Anglo-Transvaal Consolidated Investment Group (Anglovaal) and United States Steel formerly controlled the Atok mine, (Atok Platinum Mines Pty. Ltd.), at Bewaarkloff, Tvl. in the Lydenburg area, which came on stream in 1971. Planned capacity was 1.3 metric tons platinum group metals. Reserves could support an eventual output of 10 tons of PGM's a year. There is scope for considerable expansion when needed, (up to *10 tons PGM's a year*, of which two thirds in Pt). Atok has accumulated losses of $1,048,800 by June, 1977.

Atok has had its output refined at *Falconbridge's* plant in Norway.

Impala Platinum Ltd. (Union Corporation, with INCO of Canada, formerly named International Nickel of Canada)

The Impala Platinum Ltd. company is tightly held by seven companies, (e.g. Union Corporation), but is controlled and administered by the Union Corporation General Finance Group of South Africa. In addition to the Union Corporation Group's 58.44 per cent interest, *INCO of Canada* has a *10 per cent interest* in Impala; Bishopsgate Platinum and subsidiary 21.56%, National Selections 5 per cent and Industrial Selections 5 per cent. Ayrton Metals Ltd. of England, (now wholly owned by Impala), acts as selling agent in Europe. Impala have their own New York marketing office.

The mine, concentrator and smelter complex is not in the Republic of South Africa — technically that is. From December 6, 1977, the Impala platinum mine is in the new "independent" black state of *Bophutha Tswana*, homeland of the Tswana people. The Impala mine, the major asset of the new country, will yield 30 million dollars a year in mining royalties. The Bafokeng tribe and the South African Bantu Trust receive 13 per cent of the taxable income of Impala Platinum. The new state is also rich in asbestos, chromium and vanadium.

The planned rate of production for the year ending June 30, 1976, was 21.7 metric tons, but owing to tribal fighting and a shortage of black labour, production was only 20.2 metric tons of platinum.

Output was to be expanded to 21.7 metric tons platinum in the second half of 1977, and *nickel* output should rise with it.

Impala's main Bafokeng mine commenced production in mid-1969 and had already reached a mine capacity of 7.7 metric tons of platinum per year by the end of 1970 - earlier than expected. Ore grade is believed to be lower than Rustenburg's.

Impala has its own *nickel-copper* and precious metals refinery, (built with INCO of Canada's know-how), at Springs, Tvl., (which is not in Bophuthatswana), in South Africa. 28 metric tons PGM's per annum mine capacity was reached by late 1975.

The Impala Chairman stated that the present Bafokeng mine's lease area could sustain a production of over 31 metric tons of

platinum a year and that an adjacent area could provide a further 9 to 15 metric tons a year, if required.

Planned mined capacity is 31 metric tons of platinum a year. (Any increase in platinum output will naturally mean a higher *nickel* and palladium production.) By late 1975, Impala's share of world platinum "consumption" rose to 33 per cent, the company said.

General Motors Corporation, Detroit, and Impala entered into development contracts to enable Impala to supply GM with up to 9 metric tons of platinum and up to 4 metric tons of palladium for automotive converters per year during the years 1974 *to 1983* inclusive.

Western Platinum Ltd. (Lonrho; Superior Oil, U.S.A. and Falconbridge of Canada)

Western Platinum Ltd., is managed by Lonrho and is owned 51 per cent by Lonrho of England, *24.5 per cent by Falconbridge of Canada,* (which handles the sale of the output), and 24.5 per cent by Superior Oil of the U.S.A., which controls Falconbridge through *McIntyre Mines Ltd. of Canada.*

The mine near Marikana started producing in April, 1971. In the year ending September 30, 1976, metal production was 2.5 metric tons of platinum, 1,590 tons of *nickel* and 960 tons of copper. Output of 1 ton of palladium is assumed. Capacity is around 4.5 metric tons of PGM's. NICKEL CONTENT OF THE ORE IS SAID TO BE HIGHER THAN AT OTHER PLATINUM MINES IN THE AREA.

Problems are still reported although output in 1977 was little changed from 1976. Output will be cut back in 1978 by about 25 per cent.

NICKEL PRODUCTION from Western Platinum

	metric tons
Year ended 30 September 1973	2,585
Year ended 30 September 1974	1,724
Year ended 30 September 1975	1,542
Year ended 30 September 1976	1,590
Year ended 30 September 1977 (est.)	1,600

Western Platinum's new mine had a production target for 1972, their first full year, of 4 metric tons of platinum group metals which would mean perhaps 2.5 metric tons of platinum and about 1 ton of palladium.

Ore grades are believed to be lower than at Rustenburg. Ore reserves: estimated as 2 million metric tons grading 4.55 g. P.G.M.'s per metric ton.

Falconbridge of Canada markets the Western Platinum output. Falconbridge's Norwegian refinery took the first *nickel*-copper matte shipments early in 1972, for refining. Revenue from sales of the first refined metal available started in August, 1972. A long-term sales agreement runs through *end-1978,* so all of the output to date has been sold.

The Lonrho Group opened their own P.G.M. refinery, built with Falconbridge of Canada know-how, in April, 1974, at Brakpan in South Africa, which processes Western P.G.M. concentrates, and are building a new processing unit there which will use a new ion exchange process for extraction of Rh, Ru, Ir and Os.

RECOVERY OF INDIVIDUAL METALS FROM P.G.M. ORES IN SOUTH AFRICA

The in-plant lock-up time or time lag between mining and the eventual refining of the various metals for sale is a heavy financial burden. Mineral substances in transit through the processing pipeline must be kept at a minimum. Further delay in payment is caused by the fact that certain refined metals cannot always be sold immediately owing to poor demand and must remain in inventory, incurring interest.

PRODUCT TRANSIT TIMES

Detail	Time
Ore mined and hoisted to surface	Zero (reference point)
Ore from mine treated in plant	Plus 1 month
Transport overseas and associated delays	Plus 1½ or 2 months
COPPER-NICKEL Refining	Plus 2 months
Payment for the *COPPER-NICKEL, 22% of total revenue* (minimum):	*Zero plus 6½ months*
Platinum-Palladium-Gold Refining	Zero plus 4½ months plus 2½ months
Payment for the Platinum-Palladium-Gold, i.e. *69% of total revenue:*	*Zero plus 7½ months or more*
*Other Precious Metals Refining	Zero plus 7 months plus 9 months
Payment, i.e. the balance, *9% of total revenue:*	*Zero plus 16½ months*

Recoveries

Typically, the average percentage of metal eventually recovered in refined form is only:

77 per cent of the assayed P.G.M.'s (Platinum Group Metals) in the ore.

NICKEL: 79 per cent of the assayed *nickel* in the ore.

COPPER: 79 per cent of the assayed *copper* in the ore.

THE REST OF THESE VALUABLE METALS, i.e 23% of the P.G.M.'s, *21% of the NICKEL* and *21% of the COPPER,* CONTAINED IN THE ORE WHEN HOISTED TO THE SURFACE FOR MILLING, ARE *COMPLETELY LOST* A LOSS OF TENS OF MILLIONS OF DOLLARS A YEAR.

*Rhodium, Iridium, Ruthenium, etc.

Sources: "Mining Annual Review"; Custom Refineries.

3.37 Brazil

Brazil has substantial reserves of laterites.

NICKEL ore reserves totalling around 9 million tons were found (late in 1977) by a subsidiary of Cia. Vale do Rio Doce (CVRD) in Piaui state, about 350 km north of Sao Paulo. Latin American Commodities Report states that the ore grade varies from 1.57-1.90% metal content.

Brazil's nickel reserves were previously officially estimated at the equivalent of only 405,000 metric tons of metal.

Two belts of ultrabasic rocks, on which mines are located producing lateritic nickel ore. The 350 km. long Goias serpentine belt crosses Goias state from North to South. Nique-

landia district has proven reserves of 70 million tons of 1.7% Ni. At Barro Alto so far reserves of 35.5 million tons of 1.9% Ni being developed by West German and Canadian firms to produce by 1980 22,700 tons per annum Ni in 40% ferro-nickel.

Second belt of 250 km. through Minas Gerais from Liberdade to Ipanema. Liberdade deposit 5 million tons 1-2% Ni and Pnore close by. Pratapolis and Ipanema produce 10,000 tons ferro-nickel with 24.6% Ni. Significant deposits near Morro do Engelho near Mato Grosso border. Indications near Roraina in Brazil's far North.

Nickel Ore Production, 1976:

429,000 metric tons of ore.

Nickel output declined in 1976.

Mine Output of Nickel
(metric tons)

1970	1971	1972	1973	1974	1975	1976
2,900	3,200	3,400	2,700	3,000	3,200	2,300

Planned Capacity for 1980 — Total Brazil — 8,200 metric tons of nickel a year.

MINES

1. *Morro do Niquel S.A.*
   - — The *SLN* company of France has a 12 per cent interest.
   - — Mine and smelter at Pratapolis, State of Minas Gerais. Output started in 1962.
   - — Annual Capacity: 3,000 metric tons of nickel in ferro-nickel; eventually 5,000 tons Ni p.a.
2. *Cia. do Niquel do Brasil*
   - — Mine at Liberdade, State of Minas Gerais has closed.
   - — Product was ferro-nickel.
3. *Cia. Niquel Tocantins (VOTORANTIM), Niquelandia, State of Goias*
   - — PROJECT: EXPANSION OF EXISTING PLANT.
   - — Planned Capacity: 5,000 metric tons of nickel electro a year, perhaps capacity will go to 10,000 tons beyond 1980.
   - — Start-up Date: 1978.
4. Barro Alto deposit, State of Goias, adjacent to Tocantins. 40 million tons averaging 1.9% Ni, Open pit. Consortium — *INCO of Canada* entered into a participatory agreement in 1974 with *BAMINCO* Mineracao e Siderurgica S.A., controlled by Metallgesellschaft A.G. of West Germany and another West German company, reputedly August Thyssen, to determine the feasibility of development. INCO and its German partners have a 50 per cent holding in Baminco.
5. "Nickel project (Santa Fe?) in the State of Goias".

   Sante Fe reserves: 17.98 million metric tons.
6. *Codemin project*
   - — Goias State
   - — Brasimet

   Anglo-American Corporation of South Africa has taken a 35 per cent stake in this ferro-nickel project. A 1980 start up with 5,000 metric tons a year output is called for.
7. Cia. Vale do Rio Doce, (Docegeo), at Sao Joao do Piaui, in the inland State of Piaui. 18 million tons of ore reserves.

   PROJECT: 6,000 to 10,000 tons nickel contained a year — with a smelter.

SELF-SUFFICIENCY

Brazil aims at an output of 24,000 tons of nickel a year by 1983 so as to be self-sufficient in nickel, (with some quantity still available for export), under the National Development Program for the non-ferrous metals industry. In 1975, Brazil produced 36 per cent of its nickel consumption. The new Sao Felix hydro plant will power three new refineries.

3.38 Colombia

COLOMBIA MAY WELL BE THE NEXT COUNTRY TO PRODUCE NICKEL.

Laterite

Considerable potential in nickel. Future prospects very good. Production not expected before early 1980.

CIA. DE NIQUEL COLOMBIANO S.A.

The Cerro Matoso *U.S. $300 million* nickel project in the Montelibano district in the State of Cordoba in NW Colombia; located South of Cartagena, 250 miles NW of Bogota; is slated to start construction in February, 1978, with Bechtel, U.S.A. the contractor.

- — Partners: Colombian government's "Econiquel", (Empresa Colombiana de Niquel), the Industrial Development Institute of Colombia, (Instituto Fomento Industrial), and "Conicol", (Hanna Mining, U.S.A. and Standard Oil of California — Chevron-U.S.A.). Econiquel stated that Bechtel will supply and instal the ferro-nickel plant.
- — Billiton, the Anglo-Dutch Shell Group subsidiary, was reported to be negotiating with Hanna on participation in this venture.
- — Japanese steel mills and ferro-nickel smelters will *not* take part in Colombia's Cerro Matoso ferro-nickel project, according to Kawasaki Steel, because of the slump in the Japanese industry. Hanna Mining, which is partnering the Colombian government in the *$300 million project,* had asked the Japanese firms to acquire a 20-25% interest in the project and to receive about 10,000 tons of the ferro-nickel annually, half the rated output.
- — Could produce 20,000 to 25,000 metric tons of nickel in ferro-nickel a year, commencing end-1979 or 1980.
- — Ore reserves: estimated at 77 million tons; 1.5 per cent to 2.6 per cent nickel, averaging perhaps 2% nickel.
- — Feasibility studies were re-done in mid-1976.
- — Loan financing remains a difficulty.
- — *U.S. $50 million has already been spent* on preproduction costs and infra-structure. $20 million had been invested in the mine by late 1977.
- — Depressed nickel prices delayed the project.

3.39 Cuba

LATERITES: NICARO; MOA BAY; PUNTA GORDA.

CUBA COULD BECOME THE WORLD'S THIRD LARGEST MINE PRODUCER OF NICKEL BY THE EARLY 1990's.

N.B. *CUBA PROBABLY HAS LARGER NICKEL RESERVES THAN ANY COUNTRY IN THE WORLD.*

The Cuban Nickel Industry was nationalized in late 1960.

CUBA MAY REPRESENT THE GREATEST LAND-BASED NICKEL THREAT TO CANADA. RESUMPTION OF TRADE TIES WITH THE U.S.A. COULD LEAD TO U.S. IMPORTS OF CUBAN NICKEL — *TO THE GREAT DISADVANTAGE OF CANADA.*

IN PARTICULAR, THE U.S.A.'S ONLY LARGE PURE NICKEL REFINERY, (AMAX IN LOUISIANA), WHICH WAS ORIGINALLY DESIGNED TO USE CUBAN MATERIAL, COULD HELP TO RESTORE THIS TRADE. IT WOULD HAVE THE *TREMENDOUS MARKET ADVANTAGE* OF BEING *REFINED WITHIN U.S. BORDERS.*

Combined capacity at Nicaro and Moa is 36-40,000 metric tons of nickel a year.

Expansion to *46,500 tons* of nickel a year by *1980* is under way, with output of 90,000 tons a year perhaps by 1985.

Plans to increase its mine production to about *125,000 tons* in the late 1980's, and eventually *150,000 tons* in the early 1990's.

Nickel is second only to sugar as a source of foreign exchange for Cuba. Half of Cuba's nickel is sold for hard currency and half is sold to the Eastern Bloc. 70 per cent of Cuba's trade is with Comecon countries, U.S. $6.48 billion 1976, mostly sugar.

Cuba's Western markets for nickel have included Japan, Italy, Spain and Mexico. In October, 1977, Cuba was selling nickel to the West at the very low price of U.S. $1.92 to $1.98 a pound. The free market price range in late November, 1977 was U.S. $1.79 to $1.82. Selling nickel to major industrial countries for stainless steels, etc. has been difficult, because of the U.S. embargo on goods with any Cuban content.

Cuba owed around U.S. $1.3 billion to Western banks, mainly for trade credits.

More than half of Cuba's future nickel output may pass to COMECON Countries at an above-free-market price equivalent to U.S. $2.72 a pound of nickel contained. The Soviet Union guarantees Cuba an equivalent of this price in roubles under long term contracts. Cuba, of course, has to pay the Soviet Union (in roubles, perhaps) for the capital equipment it provides to Cuba, including the new nickel processing plants on order.

Total Cuban debt to the Soviet Union is estimated at U.S. $4.8 billion. With the purchase of Cuban sugar and nickel at above-market prices and the sale of oil at below-market prices, the accumulated Soviet subsidy of Cuba now amounts to some U.S. $8 billion. The U.S.S.R. may gradually narrow the price gap between their current tag of about half the world oil price and the eventual O.P.E.C. price. Since about half of the processing costs of laterite are for energy, such an oil price escalation (by the Soviet Union) would hurt Cuba.

CUBANIQUEL (State Organization)
formed in 1971 — part of Ministry of Foreign Trade

PLANTS: Nicaro and Moa. Atmospheric pressure leaching with ammonia; pressure leaching with sulphuric acid.

PRODUCTS: Nickel oxide-sinter, nickel oxide/powder, nickel oxide/fine, nickel and cobalt sulphide concentrates.

ANALYSIS: Typical analysis: Nickel oxide/sinter: Ni ± Co 90, Co 1.0, Fe 0.5, C 0.15, S 0.04. Nickel oxide/powder: Ni ± Co 77, Co 0.85, Fe 0.4, S 0.02. Nickel oxide/fine: Analysis is similar to nickel oxide/powder. Nickel and cobalt sulphide concentrates: Ni 50, Co 4.5, Fe 1.0, Cu 0.5, Zn 1.5, S 37, H_2O 25.

NICARO, On the Northern Coast of Oriente Province, West of Moa (originally built by Freeport Sulphur, U.S.A.)

produces about half of Cuba's nickel

— produces nickel-cobalt oxide (76 per cent Ni) and sinter

sinter contains 90 per cent nickel

capacity: 19,000 metric tons nickel contained, estimated

- 70 per cent of the oxide and sinter produced, *(CLAIMED TO BE SUPERIOR IN QUALITY TO COMPARABLE CANADIAN PRODUCTS),* is said to be exported to the West

THE LOW COPPER CONTENT OF THE OXIDE IS A *GREAT SELLING ADVANTAGE* OVER THE FERRO-NICKELS FROM OTHER COUNTRIES, AS WELL AS THE CONTENT OF CHROMIUM, PHOSPHORUS, SULPHUR AND COBALT.

Originally, the U.S. government built an ammonia leach plant in Cuba for treatment of Nicaro ores during World War II. This plant was operated by the Nicaro Nickel Company, a subsidiary of the U.S. Freeport Company, and produced a nickel oxide sinter containing 88% nickel which was shipped directly to market from the Cuban plant. The Nicaro ores were largely of the silicate type and not amenable to acid leaching.

MOA BAY, Near the Eastern Tip of the Island (operation originally built by Freeport Sulphur, U.S.A.)

The subsequently explored Moa Bay deposits were found to be predominantly limonitic types with low magnesia and high cobalt content. It was later known that an acid leach process at elevated temperature and pressure would yield 90% of the contained nickel compared with over 76% recovery at Nicaro. The Moa Bay plant was started up late in 1957 and consisted of open pit mining, crushing and water screening to a slurry before applying the aforementioned leach method. Since this process utilized sulphuric acid, the product consisted of a nickel sulphide slurry, which in turn was shipped to the Port Nickel, Louisiana refinery in the U.S.

— Moa Bay produces about half of Cuba's nickel output.

— open pit mine.

— produces nickel-cobalt sulphide.

concentrate grades 61 per cent nickel.
capacity: 19,000 metric tons nickel contained, estimated.

leach refining.

EXPANSION

Three new plants will probably be in production by 1985. YEARLY OUTPUT OF 100,000 TONS OF NICKEL BY CUBA BY 1985 IS THEIR GOAL.

Phase I — Completion 1980 (could take to 1982 or 1983).

— Expansion of Nicaro capacity by 25 per cent to 22,500 metric tons of nickel contained a year.

— Expansion of Moa Bay capacity by 30 per cent to 24,000 tons a year.

Phase II — One new nickel processing plant at Punta Gorda will be constructed soon with a production capacity of 30,000 tons of nickel a year.

Completion: 1983.

— Another similar complex 3 miles further East is planned.

Ready 1985 86.

The building of two additional expansion plants, capable of producing a further 60,000 tpy, has been under discussion with the Comecon countries. Cuba became a member of Comecon in 1972.

Phase III — An additional plant at Moa, to bring Cuba's output up to 150,000 tons of nickel by 1990.

In 1977, a U.N. technical mission submitted, (as part of the very large expansion plans), a study for the construction of a 20 metric tons a day pilot plant for the process development and testing on laterite ores in the Moa area. This, it was estimated, would cost some U.S. $2.5 million, of which $1 million would be supplied from the United Nations Development Programme, (UNDP). The bulk of the finance required for the major mine and plant developments will presumably come from Comecon, including the U.S.S.R.; much of this in the form of credits for the purchase of mining and processing equipment.

PUNTA GORDA DEPOSIT, (2 miles East of Moa)

The Gipronikel Institute of Leningrad designed a new nickel-cobalt extraction plant, (already under construction).

— Planned: 30,000 metric tons of nickel plus cobalt a year (by 1983) (part of *U.S. $600 million* below).

— Reserves sufficient for 50 years.

— A higher recovery rate than Nicaro is anticipated.

— The laterites have a lower alumina content than the Nicaro area.

— Czech engineers may be involved.

MAYARI — 50,000 tons per annum (1.3% Ni) ore produced at Mayari, East Cuba.

PENAROS — no details. Potential may be 20-22,000 metric tons of nickel per annum.

COBALT — Cuba currently produces about 1,600 tons of cobalt a year as a by-product of nickel mining.

CUBAN MATERIAL FOR THE U.S.S.R

The Soviet Union is said to refine up to 65 per cent, say 20,000 to 25,000 metric tons, of Cuba's nickel output — *at Monchegorsk* in Russia it is believed. Czechoslovakia may be taking the balance. Russia is financing a *U.S. $600 million expansion* of Cuban nickel production — target 90,000 metric tons of nickel a year by 1985, including the new Soviet Gipronikel designed plant mentioned above at Punta Gorda to produce 30,000 tons a year of nickel plus cobalt. An eventual Cuban mine output capacity of 150,000 tons is planned.

Stainless Steel Plant — to utilize some of the primary nickel

A 100,000 metric tons of stainless steel a year plant is planned for the mid-1980's under a *mutual cooperation agreement with CANADA*. It would consume up to 5,000 metric tons of nickel oxide a year. Surveyor, Nenninger & Chenevert of Montreal submitted a feasibility study to Cuba in October, 1977.

3.40 Dominican Republic

Laterite reserves: 70 million tons 1.6% Ni and approximately 16% Fe.

FALCONDO (Falconbridge Dominicana C. por A.)

A Falconbridge Nickel of Canada mine project — 65.7 per cent holding.

Armco Steel Corporation, U.S.A. is the next largest shareholder and the Dominican government holds 9.5 per cent.

— open pit mine at Bonao, Loma de la Peguera, Yuna River Valley.

— commenced production at end-1971.

— capacity *30,000 metric tons per year of nickel* contained in ferro-nickel, (38 to 40 per cent Ni content). (Has produced *above* capacity at 31,000 tons.)

plant cost — *$195 million* in 1971.

— operating cost — $1.39 per pound of nickel (contained).

- in 1974 fuel costs quadrupled and total operating costs nearly doubled. Further, under term sales contracts, deliveries were made at $1.46 a pound, compared to the market price of $2.01.

— loans total $180 million. During 1976, interest and principal payments on the long term debt amounted to RD$30.73 million, (U.S. $30.73 million).

MINE OUTPUT OF NICKEL

(metric tons)

1971	1972	1973	1974	1975	1976
200	17,400	30,100	30,500	26,900	24,400

Oil price increases and increased labour costs have eroded the profitability of this venture but it is probably higher in profits contribution than Falconbridge's Sudbury, Ontario operations.

Nickel output has been cut back noticeably from the 1974 high. 550 of the 2,100 workers had been laid off at end-1977. The operation is meeting the environmental standards of the Province of Ontario until local standards have been set.

3.41 Guatemala

"EXMIBAL", (Exploraciones y Explotaciones Mineras Izabal, S.A.)

80 per cent owned by *INCO Ltd. of Canada;* 20 per cent by Hanna Mining of Cleveland, Ohio. The government of Guatemala and private interests in Central America will eventually acquire about 37 per cent of Exmibal.

Open pit laterite mine at Lake Izabal, near El Estor; on stream in 1977. Ore grade: average 1.9 per cent nickel.

Mining rights have been granted for 40 years.

One lateritic deposit near Exmibal reportedly contains 50 million tons averaging 1.32 per cent nickel.

Mine is called "NIQUEGUA", which has a Processing Plant.

Commercial level production is expected to be achieved in the second quarter, 1978. Production will be held to levels substantially below those previously planned for 1978 and employment levels will be lower.

INCO has given completion guarantees to the Exmibal project and, in addition, under the "price support agreement", INCO has agreed, subject to the occurrence of events of force majeure, to *purchase Exmibal's production at $2.00 per pound in 1977, at $2.10 per pound* in 1978 and 1979, and thereafter at prices extended to meet Exmibal's operating and debt service cost.

Exmibal's production rate is expected to be about 12,700 metric tons annually and the grade of ore treated in the processing plant during the first 10 years of operation will vary from 2.1% to 1.75% nickel. Capital cost would amount to $224 million plus 3% current escalation, i.e. $231 million at 12,700 metric tons per year annual capacity. *It is stated that INCO's estimate of the economic viability of the Exmibal project based upon current depressed nickel prices and the project's heavier reliance upon fuel oil, is that the project would operate at a loss.* The cost of fuel oil represents slightly over 50% of Exmibal's total cash operating costs. It is interesting to note that this price support agreement was completed by INCO *on October 22, 1976,* shortly after they announced a price increase to $2.41 per pound for nickel cathode, (later rescinded).

Total Cost:

U.S. $231 million, (about *twice* the cost forecast in 1972).

Capital cost per pound of annual nickel output capacity: U.S. $8.25.

Loans:

1) The Government of Canada's Export Development Corporation made available low-interest loans totalling some $70 million to INCO's nickel-mining subsidiaries in *Guatemala, Indonesia* and New Caledonia.

   The Chairman, John MacDonald, is reported to have said that E.D.C. loaned INCO $20.75 million for Guatemala and $57.25 million for Indonesia in order to get equipment orders for Canadian suppliers. The allegation had been made that the E.D.C. had effectively been exporting jobs from Canada.

2) INCO secured loans of U.S. $15 million from the World Bank affiliate International Finance Corp. and reportedly U.S. $100 million from the U.S. Export-Import Bank. *Debt repayment will begin in 1979.* As of September 30, 1977, $202 million had been invested in the project. Long-term senior loans total $104 million substantially all of which had been drawn as of October 14, 1977. The institutions providing this debt include the International Finance Corporation, $15 million, Central Bank for Economic Integration, Export-Import Bank U.S. $30 million, plus export credit agencies of the U.S., Canada, Norway and United Kingdom, and various commercial banks. Exmibal's authorized capital of $30 million has been fully paid in by INCO and Hanna and $20 million of subordinated advances were provided to Exmibal also by INCO and Hanna prior to 1973.

n.b. Strict loan repayment schedules for these expensive overseas ventures, (Indonesia and *Guatemala* — total cost to INCO: $895 million), will put INCO under severe pressure to sell the Indonesian and Guatemalan output as priority over the Canadian (Ontario and Manitoba) nickel. INCO started to cut back Ontario mine and refinery output and reduce employment in 1977.

EMPLOYMENT — 900 will be employed eventually.

TAXES — 5 year tax holiday.

CAPACITY

Stage I

Up to 13,000 metric tons of nickel in matte per year were planned in the first stage. There was no finished nickel production in 1977.

Stage II

No details.

PRODUCT

Nickel matte (75% Ni). This will go to INCO's U.K. refinery at Clydach, Wales, which is being expanded at a cost of *U.S. $13.8 million* for a new fluid bed roasting plant and sulphuric acid plant, which has a completion date of end-1978. "Can serve as feed to any of INCO's refineries in Canada and U.K." — Mr. E. Carter, President of INCO.

The nickel matte goes by barge about 80 kilometres via Lake Izabel and the Rio Dolce river to the Guatemalan Caribbean port of Puerto Barrios, for ocean shipment to Clydach, Wales, for refining.

3.42 Venezuela

Loma de Hierro deposit Southwest of Caracas, in the States of Araqua and Miranda.

French "SLN" company had a 49 per cent interest, but the Venezuelan government has taken over the project.

— could perhaps produce 20,000 tons of nickel in ferro-nickel a year, (25% Ni content).

ore reserves estimated at 55 million tons, averaging 1.65 per cent nickel.

3.43 Puerto Rico (U.S.A.)

Guanajibo and Las Mesas laterite deposits of nickel at Mayaguez, on the Southwest side of the Island.

— Of great interest to the U.S.A., which currently imports about 70 per cent of the nickel it needs.

— U.O.P. (Universal Oil Products Co.) is testing a hydro-metallurgical process.

— 70 to 90 million tons of ore, averaging 0.88 per cent nickel, which is lower than in the neighbouring Dominican Republic and Cuba.

— Might produce 15,000 metric tons of nickel a year.

— Might eventually produce 500,000 tons of nickel in all.

— Testing, R. and D. continuing.

3.44 U.S.A.

LATERITES

HANNA MINING CO.

Open pit mine at Riddle, OR, U.S.A., capacity about 12,000 metric tons of recovered nickel content per year — Closed from January 14, 1978 to February 27, 1978 owing to poor nickel demand. Affects 400 employees.

Neither the U.S., nor its overseas possessions have at any time been significant world producers of nickel from domestic ore sources. At the present time, The Hanna Mining Company is the sole U.S. producer of domestic nickel ore and with 1976 production of approximately 11,900 metric tons this can meet only a small proportion of annual consumer needs.

Additional primary nickel production in the U.S.A. is obtained as a by-product of copper mining, with the material being recovered as nickel salts in copper refineries. It should be noted that the by-product statistics include some refined nickel recovery from scrap as well as nickel salts. Also, the data for total mine production is reported prior to mill and smelter recovery, while the Hanna data is reported in their annual report as production contained in ferronickel.

The Hanna Mining Company's ore deposit is located in what is called "Nickel Mountain" at Riddle, Oregon, U.S.A. These laterite ores were discovered in 1864 but it was not until 1954 that the mine was developed. This ore averaged about 1.5 per cent nickel at the start of production.

The principal ore mineral is garnierite, as with most of the world's economic laterite nickel deposits. From start-up until the end of 1976, it is estimated that some 223,000 metric tons of nickel contained in ferronickel have been produced.

3.45 Other Countries

Burma — Exporting 100 metric tons/year of nickel in matte from smelter at Namtu to West Germany, produced from laterite ores at Bawdin. Silicious nickel ores East of Indo-Burmese fault.

At Mwetaung, 20 km. North of Kalewa coal district, 100 million tons of probable reserves at 1.5% Ni. At Tagaungtaung, 50 km. South West Mwetaung, 1.3 million tons, 2% Ni.

Burundi — Extensive Nickel, Copper and Platinum discoveries in 1973.

Ethiopia — Prospecting for lateritic deposits near Sidamo, 200 miles West of Addis Abbaba. (*Geologija*, Ljubljana, 1966 pp. 413-437.)

Greenland — Ultrabasics near Cape Farewell considered promising for Copper, Nickel and Platinum mineralization.

Guinea — Several billion tons of reserves of iron ore, 47-51% Fe, close to Conakry; metallurgically unsuitable because of Ni content to 0.1% and Cu content to 1%.

Guyana — Some nickel deposits identified — so far uneconomical.

Italy — Small scale production near Varollo (Piedmont) and in South East Sardinia discontinued as uneconomical.

Ivory Coast — Late in 1976, *Falconbridge Nickel Mines of Canada* were reported to be discussing with the Government of the Ivory Coast the possible development of nickel deposits at Sipilou, Foungouesso and Moyango in the East of the country. Drilling samples are said to be encouraging.

Malagasy (Madagascar) — Near Ambatory-Amalemaj, 120 million tons 1.2% Ni.

Morocco — Near Aghbar (former Bou Azzer), 250 km. inland from Agadir, production 12,000 tons per annum concentrates, 14% Co, 1-2% Ni and 40% As planned for export to France and China; sufficient for a decade. Output: 500 tons of nickel in concentrates from 1974 onwards.

Saudi Arabia — Complex lead-zinc-copper-nickel ores with some gold and silver, with plus 1% Ni, near Wadi Quatan.

Zambia — Up to 0.2% Ni and other metals in various iron deposits.

Norway — Produces 400 metric tons a year of nickel in ore and Falconbridge continues exploration.

3.46 Sea-Bed Mining of Nickel and the United Nations Law of the Sea Conference

SEA-BED NICKEL

The oceans of the world, particularly the Pacific, are thought to contain as much as 80 million tons of nickel — as well as many other metals.

The principal commercially-valuable metals which will come from the sea-bed nodules, probably in the early or mid-1980's, just happen to be those which are mined in Sudbury, Ontario, Canada, i.e.

1) *Nickel*, of which Sudbury, Ontario alone is presently the world's largest producer, (about 30 per cent of world nickel output).

2) *Cobalt*, (Sudbury is the world's *third* largest producer), and

3) *Copper*. The annual value of Ontario's mine deliveries of copper averaged about $425 million in the last two reported years, representing about one third of Canada's output, or about 13 per cent of the Western World's mine output of copper. However, *Nickel* is the metal that matters most in sea bed mining economics.

HENCE ONTARIO'S CONCERN OVER THE LAW OF THE SEA PROPOSALS COVERING DEEP SEA-BED MINING OF METALS.

The other major mine sources of nickel at present are (in order of importance after Canada): Russia, French New Caledonia in the Pacific, Australia, Cuba, Dominican Republic, Southern Africa and Greece. There are new nickel mines or expansions coming on stream in Russia, Australia, Botswana, Indonesia (INCO), Guatemala (INCO), and the Philippines add to the competition.

The United States mines very little nickel but is the Western World's largest *consumer* of nickel, using some 35 per cent of the Western World's mine output.

The U.S.A. aims to become self-sufficient in nickel. Currently it has only a small domestic mine output. It should benefit enormously from sea bed nickel production.

The U.S. Secretary of the Interior has said that:

1) Sea bed mining by U.S. companies from the early 1980's on, would mean that *within 10 years* of the first production the U.S. would *reduce* by 50 per cent its nickel import needs, (*Ontario* being the largest source at the moment), and

2) Imports of cobalt into the U.S.A. would be completely eliminated.

The item of greatest concern to Ontario has been the proposal of May 5th, 1976, that all increases in world nickel consumption would come from mining the deep-sea metals.

THE SINGLE MOST IMPORTANT QUESTION THAT CAN BE ASKED ABOUT NICKEL IS "HOW MUCH WILL THE WORLD CONSUME IN THE FUTURE".

There is great danger for Ontario in the alarming assumption that the average increase in world demend for, i.e. consumption of, nickel is likely to be six per cent a year, which was enshrined in the candidate 1976 Revised Single Negotiating Text of the proposed new U.N. Law of the Sea. Ontario believes that 3 or 4 per cent a year is a more realistic average rate of increase in use.

1) In 1975, the world consumed less nickel than in any recent year. 1976 and 1977 saw only a slight improvement.

2) Nickel demand is cyclical. There are bad years and good.

3) Canadian nickel, (that's largely the Sudbury, Ontario, output), *must be exported* to *those who are willing to buy it.*

4) Canada can only consume about five per cent of its mined nickel output.

What would happen to Sudbury in future years of exceptionally low demand for nickel? The Ontario Government has had some success in getting its concerns across. As a corporation operating in many countries, INCO Ltd., (INCO Metals Company), the largest mine producer of nickel in Ontario, obviously cannot confine its concerns to Sudbury. Its interests as a multi-national corporation are, unfortunately, not identical with those of the Province.

The U.S. consortium in which INCO is a member was to take delivery in the fall of 1977 of a ship equipped with deep sea drilling and recovery equipment. INCO has investments in various sea bed mining ventures and it also has nickel mines outside of Canada now, like Falconbridge.

As a member of a consortium with a U.S. $40 million project, INCO is spending money on sea bed nickel mining research and the necessary metallurgy. It may prove to be a most valuable investment. INCO has two reasons to be concerned about sea bed mining. One is its obvious self-interest in any nickel development. INCO would prefer not to see its land-based Canadian nickel resources jeopardized in any way. However, if ocean mining is authorized by the United Nations, or by the U.S.A. unilaterally, INCO as a major world producer of nickel, copper etc. does not want to be dealt out of the game.

INCO will be processing sea-bed nodules from the Pacific in 1978 at its Port Colborne, Ontario research facility.

The Canadian External Affairs Minister has stated that he is satisfied that the U.S.A. does not intend to solve this problem of sea bed nickel at Canadian expense.

U.N. COMMITTEE

The United Nations Economic and Social Council's Committee on Natural Resources commented in March, 1977 as follows:

"Impact of sea bed nickel on the metal market"

"On the basis of available information, and assuming that the results of full-scale tests are acceptable and that the legal problems have been resolved, it is conceivable that *sea bed* nodule *mining could start* in the *early or mid-1980's*. If this is indeed the case, then, on the basis of factors such as the number of existing consortia, the novelty of the technology and the operation, it may be assumed that by 1985, the total tonnage of dry nodules recovered annually could range from 5 to 10 million tons.

The potential *contribution* of ocean mining to the *world supply* of minerals in the mid-1980's *could be considerable*, as shown by the following estimates of mineral production from nodules during that period:

	Nickel (metric tons)
At a 5-million-ton/yr level	75,000
At a 10-million-ton/yr level	150,000
Estimated "world" consumption, *1985*	
Primary mineral consumption *a/*	970,000
Total consumption *b/*	1,220,000
Share of "world" market, assuming a 5-million-ton/yr level *a/ b/*	7.8 per cent; 6.1 per cent
Share of world market, assuming a 10-million-ton/yr level *a/ b/*	15.5 per cent; 12.3 per cent

a/ United States of America, Department of the Interior, "Mineral facts and problems", *Bureau of Mines Bulletin 667* (Washington, D.C., 1976).

b/ "Economic implications of sea bed mineral development in the international area" (A/CONF.62/25).

Depending on the projected consumption which, as can be seen, varies considerably with the underlying assumptions and growth rates, cobalt will be especially affected, with one third to one half originating from the ocean under the high-production alternative. (In Canada, the Soviet Union and elsewhere, cobalt is a by-product of land-based nickel mining.) *Nickel* supplies will be moderately affected".

The above United Nations view contrasts in some respects with others, particularly on the level of future world consumption of nickel.

3.47 Sulphide Production

Nickel ores are commonly divided into two broad categories, namely sulphides and laterites. This classification is not precise but is a convenient way of looking at the entire industry.

For instance, with the sulphide ores and their minerals, arsenides, antimonides, and arsenate minerals are often associated. However, this is a somewhat academic qualification since pentlandite (a nickel, iron sulphide) accounts for virtually all of the "sulphide" production. Pyrrhotite is often considered a nickel mineral but it is actually an iron sulphide which frequently has grains of pentlandite within it.

The ores of some of the earliest nickel mines in the world were sulphide types. For example, the Schneeberg-Annaberg district in Germany was mined for silver in 1474 and 300 years later some of the deposits were worked for nickel when the technology became known. Other European sulphide deposits were worked in Chalanches, France; Klefva, Sweden; and Evje (Flaad), Norway.

The largest developed nickel sulphide deposits are located at or near Sudbury, Ontario, the principal companies involved being INCO Limited and Falconbridge Nickel Mines Limited. In 1976 these two companies accounted for about 65% of Western World sulphide nickel mine production.

After Canada, Russia is the next most important producer, then New Caledonia, Australia, with Western Mining, Anaconda — R.T.Z. joint venture at Redross, Great Boulder Mines (at Scotia and Carr Boyd Rocks), Selcast Exploration (Spargoville) and Western Selcast/MIM (Agnew).

MICROBIAL MINERS

The use of microbes in mining and metallurgy is a relatively new idea, i.e. inviting bacteria to recover nickel, copper and uranium from unworkable or uneconomic rocks or from waste dumps.

In 1974 the Western Mining Corporation of Western Australia announced a microbiological method for winning another metal, *nickel*, from low-grade ores. The rock is sprayed with a dilute solution of sulphuric acid containing strains of *Thiobacillus*. Percolating through the ore, the liquid extracts high concentrations of nickel, which can then be recovered from the solution by electrolysis.

Thiobacillus ferroxidans has been isolated from water flowing out of waste dumps in Britain containing copper sulphide ore. The bacterium releases at least fifty parts per million of copper from the ore, liberating it into solution. Thiobacillus is an autotroph, which can oxidize iron, copper and other pyrites, solubilizing the metals they contain. The potential value of this leaching process in extracting metals from inaccessible rocks, and from ores and wastes poor in metals, is obvious.

At the Stanrock Uranium Mines in Ontario, Canada, some eight thousand kilograms of uranium oxide were leached monthly from rocks in situ. After the microbes have done their work on a mine face, the wall is hosed down and the water pumped to the surface. Though the solution contains only a low concentration of uranium the technique is viable because there is no need to haul up the mine shaft large quantities of rock containing feeble amounts of metal. The new Agnew uranium mine in Ontario is using a similar technique.

3.48 Laterite Production

In the preceding section two major categories of nickel ores were identified and minerals of the sulfide type were listed. Laterite deposits — the second category — are generally composed of a weathered concentration of garnierite. This mineral is a complex hydrous nickel-magnesium silicate and is in fact a generic term covering a host of similar minerals with roughly the same composition. Another common lateric mineral is nickeliferous limonite which contains iron, oxygen and water.

These deposits were originally silicates and the combined action of air, water, heat and cold decomposed the rock into soil and clay. In tropical climates this action tends to separate nickel from silicon and thus not only aids in concentration of the metal, but also facilitates metallurgical recovery. Generally this enrichment process produces ore with 6 times the concentration of nickel as was present in the original igneous rock. Laterite deposits are also characterized by a capping of iron rich, low nickel laterite soil, but there is never complete separation into two zones of iron and nickel.

The most well known and exploited laterite deposits in the world are found in New Caledonia in the South Pacific, northeast of Australia. Prior to discovery of these extensive deposits in the mid 1800's, world nickel production and resources were limited. With their development by Societe Anonyme Le Nickel, (SLN) New Caledonia became the world's leading producer of nickel in 1875, retaining this position until 1905 when Canadian production began to predominate.

3.49 World Metal Production (in Primary Metallic Form) and Capacity

NICKEL REFINERIES

About ten years ago, only seven countries, Canada, the U.S.S.R., the French and the Cubans, Japan, the U.K. and Norway had operating nickel refineries of any importance.

To handle the refining of the new mine output, particularly in developing countries, some major plants were constructed, including:

1) Falconbridge of Canada built a new refinery producing ferronickel in the Dominican Republic, which came on stream in 1972.
2) The old Freeport nickel refinery in Louisiana, U.S.A., (never used because of Castro's 1960 takeover of Cuba), was reactivated by AMAX Inc., U.S.A., in 1974; currently handling certain output from Botswana, New Caledonia, etc.
3) Marinduque opened a new nickel refinery in the Philippines in 1975.
4) Queensland Nickel Pty. Ltd. built a nickel refinery at Yabulu, near Townsville, Queensland, Australia, officially operative in 1976.
5) INCO is expanding the capacity of its 75-year old nickel refinery in Clydach, U.K., to handle some of its Indonesian and Guatemala output — to come on stream in 1978.

WORLD METAL PRODUCTION AND CAPACITY OF REFINED NICKEL

INTRODUCTION

Nickel producers and the major industry segments who purchase nickel have come to accept two general classifications (Class I and Class II*) in order to describe the several physical forms and various purity levels of nickel products supplied from the producers, and used within the industry. There is no nickel company in the Western World producing a complete product line at the present. World production of refined nickel from 1947 is shown in the accompanying table.

Estimated total world capacity of refined Class I nickel in 1978 is 563,000 metric tons per year and 454,000 Class II metric tons per year or a total of 1,017,000 metric tons per year. By the end of 1980 capacity will be:

			Percent
Class I	578,000 metric tons	per year	52.3%
Class II	528,000 metric tons	per year	47.7%
Total	1,106,000 metric tons	per year	100.0%

In other words, total refinery capacity including new projects will increase 8.7% by 1980 of which 83% of the increase will be Class II.

It is evident that refined nickel capacity including all Class I and Class II nickel products of 1,106,000 metric tons will be much higher than consumption which will be about 700,000 metric tons. There is also a significant imbalance of consumption in the major consuming areas as compared to refined nickel capacity. (eg.)

Estimated 1980

	Consumption	Capacity
Europe	28.5%	15.0%
North America	25.7%	30.0%
Asia and Australia	20.0%	29.5%
Cuba & Eastern Bloc	25.0%	25.0%

The over capacity developed in the Asian area will be striving for market share, particularly in Europe where refined nickel capacity will be below consumption.

Class I Nickel Products

Class I Nickel Products exhibit a very low level of impurities and a nickel content above 99.25% nickel of which two products are considered suitable for universal applications. Electrolytic nickel cathode and carbonyl nickel pellets are theoretically applicable for all alloying uses and electroplating.

Class II Nickel Products

Class II nickel products include considerable grades of ferro nickel smelted (or about to be smelted by 1980) by 16 producers including Russia, Yugoslavia and Albania. Nickel oxides including oxide sinter is also a Class II product as well as special nickel alloys produced primarily by INCO for use in primary steel and ferrous and nonferrous casting melts. Nickel content of the various Class II products range from about 20% to 95% nickel.

* George Bonar, The Nickel Industry — a reference study, Canavest House Limited, 1971.

TABLE 3.49

PRODUCTION OF REFINED NICKEL

Thousand metric tons	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Europe	24.3	28.0	34.5	35.1	40.5	40.9	43.7	48.1	51.4	52.3
Asia	—	—	—	—	0.2	1.2	2.9	4.3	6.6	11.0
Africa	—	—	—	—	—	—	—	—	0.4	0.8
America	85.5	90.0	80.0	82.7	87.2	99.0	107.5	120.1	132.4	136.9
Australia and Oceania		0.5	0.8	0.4	1.2	3.2	2.5	2.6	3.7	3.6
Western Countries	109.8	118.5	115.3	118.2	129.1	144.3	156.6	175.1	194.5	204.6
Eastern Countries*	16.2	17.8	25.4	29.6	33.7	37.8	41.0	43.0	45.1	48.5
Total World	126.0	136.3	140.7	147.8	162.8	182.1	197.6	218.1	239.6	253.1

Thousand metric tons	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Europe	54.9	56.2	61.7	78.2	86.4	84.0	79.1	79.9	83.6	85.9
Asia	15.8	6.7	12.9	17.8	23.1	15.1	22.0	27.5	26.5	29.8
Africa	1.3	1.2	1.2	1.2	1.2	2.5	2.5	2.5	3.0	5.4
America	148.6	101.0	143.4	156.4	137.1	155.1	131.2	152.1	174.1	143.2
Australia and Oceania	3.2	2.3	4.9	11.4	13.4	5.5	8.3	13.3	15.6	20.3
Western Countries	223.8	167.4	224.1	265.0	277.7	282.2	265.1	299.4	328.6	284.6
Eastern Countries*	51.6	55.3	56.0	61.8	95.3	104.0	106.0	110.0	111.7	117.2
Total World	275.4	222.7	280.1	326.8	356.5	366.2	349.1	385.3	414.5	401.8

Thousand metric tons	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Europe	85.3	92.3	85.0	99.4	105.1	105.3	109.6	110.0	108.1	104.6
Asia	41.6	53.7	68.5	89.8	102.6	79.5	87.7	104.6	87.3	112.8
Africa	5.7	7.5	10.0	14.0	19.0	23.0	26.0	29.0	27.0	32.0
America	176.4	169.4	148.1	223.8	193.3	166.3	219.3	242.4	227.0	235.5
Australia and Oceania	20.7	22.4	23.9	29.0	46.3	52.4	55.6	69.0	89.1	84.2
Western Countries	329.7	345.3	335.5	456.0	466.3	426.5	498.2	555.0	538.5	569.1
Eastern Countries*	133.7	142.0	145.0	151.1	153.3	156.9	158.0	161.1	173.6	182.1
Total World	463.4	487.3	480.5	607.1	619.6	583.4	656.2	716.1	712.1	751.2

* Eastern Countries includes Cuba.
Source: Metallgesellschaft, Metal Statistics 1947 - 1976.

3.50 Electrolytic Nickel Cathode (99.5% nickel minimum)

Inco Metals Company	**Port Colborne, Ontario	
	20,000 tons	per year
	— Thompson, Manitoba	
	52,000 tons	per year
Falconbridge Nickel	- Kristiansand, Norway	
	45,000 tons	per year
- Outokumpu, Finland	12,000 tons	per year
Rustenburg Platinum	- South Africa	
	14,000 tons	per year
Shimura Kako	Japan	
	6,600 tons	
Sumitomo Metal	Japan	
	18,000 tons	
- Empress Nickel Mining	Rhodesia	
	5,000 tons	
- Rhodesian Nickel	Rhodesia	
	2,800 tons	
Noril'sk, Russia		
- Pechenganickel Complex	Russia	
	141,000 tons	
Monchegorsk Refiners, Russia		
Other Eastern Bloc	10,100 tons	
S.L.N., Le Havre	France	
	15,000 tons	(1979)

Total World Nickel capacity electrolytic cathode is 326,500 metric tons in 1978, increasing to 341,500 in 1980.

3.51 Pellet and Granules

(99.7% to 99.97% Nickel)

- Inco, Copper Cliff, Ontario	— 45,400 tons, carbonyl nickel pellets. Nickel 99.97%
Inco, Clydach, Wales United Kingdom	45,000 tons, carbonyl nickel
- Falconbridge, Kristiansand, Norway	Nickel 98 granules, 99.7% nickel. Capacity (?) (included in electrolytic nickel capacity)

TOTAL CAPACITY: 90,400 metric tons per year - pellets and granules.

** "S" Nickel Rounds .02% nominal sulfur.

3.52 Briquettes, Rondelles and Powder (99.3% to 99.9% Nickel)

Le Nickel, SLN, Le Havre, France
10,000 tons, rondelles 99.3% Nickel (includes some powder)

Western Mining, Kwinana, Australia
30,000 tons, briquettes and powder

- Sherritt Gordon Mines Limited, Alberta, Canada
18,100 tons, briquettes and powder

- Marinduque Mining, Philippines
34,000 tons, briquettes

Amax Nickel, Louisiana, U.S.A.
35,000 tons, briquettes

Inco, Copper Cliff, Ontario
11,000 tons, powder

- Inco, Clydach, Wales, U.K.
(Capacity included in pellet capacity)

- Impala Platinum — South Africa
8,000 tons, briquettes and powder

1980 Total World Nickel Contained in Briquettes — Capacity 146,100 tons per year.

3.53 Ferro Nickel Producers and Capacity

(Nickel Content of Ferro Nickel)

SLN, New Caledonia, Four Grades, FN1 to FN4, Nickel 20% to 30%, Carbon 0.03% to 2.0%.
Capacity 71,000 tons, increases to 100,000 tons 1980.

- Falconbridge, Dominicana, 35% Nickel pigs. Capacity 30,000 tons.

Pacific Metals, Japan, two grades ingot 17 to 28% Nickel, 2 grades shot 18 to 45% Nickel. Capacity 36,000 tons.

Nippon Mining, Japan, 18-23% Nickel ingot. Capacity 19,600 tons.

Nippon Yakin, Japan, 16-22% Nickel ingot and luppen. Capacity 19,800 tons.

Shimura Kako, Japan, high and low carbon 18-23% nickel ingot, capacity 5,300 tons.

Sumitomo, Japan, 23-28% Nickel ingot. Capacity 22,300 tons.

Larco, Larymna Greece, 24-33% Nickel pig. Capacity 18,000 tons per year.

P.T. Aneka Tambang, Indonesia (1980), 4,000 tons per year.

Hanna Mining Company — Riddle, Oregon, U.S.A. 50% nickel pig, capacity 14,000 tons per year.

Morro do Niquel, Brazil, 30% nickel ingot. Capacity 3,000 tons per year.

- Inco, Copper Cliff, Ontario, 29% nickel iron powder. Capacity 1,500 tons per year.

FeniNickel, Yugoslavia 25% Nickel ingot
Capacity 16,000 tons per year
Expansion 11,000 tons per year 1978
Total 27,000 tons per year 1980.

— Elbasan, Albania, 25% nickel ingot. Capacity 1,000 tons per year.

— Orsk, Ukraine, and Ufaley Smelters, Russia. Grades not known. Capacity 27,000 tons nickel per year.

Total World Nickel Capacity in Ferro Nickel 284,500 metric tons per year 1978, and 328,500 metric tons 1980.

3.54 Nickel Oxides –

(Nickel Content 75% to 95%)

— Queensland Nickel, Greenvale, Australia
90% Nickel oxide, Briquettes. Capacity 25,000 tons per year.

— *Inco, Copper Cliff, Ontario
Capacity 77,000 tons, nickel oxide 75% as sinter which includes the 45,400 tons per year chlorine reduction facilities for production of Incomet (95% Nickel).

Inco, Port Colborne, Ontario
30,000 tons utility nickel shot and pig.

— Inco, Copper Cliff Iron Ore Plant
Capacity 6,000 tons per year soluble nickel oxide (77% Nickel).

— Tokyo Nickel, Japan 75% Nickel sinter. Capacity 8,000 tons per year.

- Nippon Nickel, Japan 75% Nickel oxide granules. Capacity 7,000 tons per year.

- NICARO and Moa Bay (Cuba)
Nicaro — 75% Nickel Oxide
Moa Bay — 90% Nickel Oxide
Total Capacity 36,000 tons per year, 46,500 tons (1980).

Total World Nickel Capacity in Nickel Oxides: 189,000 metric tons per year 1978 increasing to 190,500 metric tons in 1980.

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* Inco, Copper Cliff, Ontario complex exhibits designed production flexibility. It is capable of generating various purity levels of nickel oxide such that capacity can be rationalized in accordance with market demand forecasts or the need to produce feed for the refineries for the purpose of maximizing return on investment. Various purity levels of nickel oxide can be fed to Port Colborne refinery, Clydach refinery or can be reduced to marketable Sinter 75 or further reduced by chlorination reduction to yield Incomet (95% nickel) or fed to the nickel carbonyl, Copper Cliff plant. Capacity appears to be about 131,000 tons of nickel contained in refined products. The balance of smelter capacity can be shipped to Port Colborne, Ontario and Clydach, Wales, together with 30,000 tons (nickel) from excess capacity of the Thompson, Manitoba plant.

The announced capacities of Inco — Exmibal, Guatemala (15,700 tons per year and P.T. Inco-International Nickel Indonesia 45,400 tons per year, in addition to excess smelter capacity of Copper Cliff, Ontario, and Thompson, Manitoba, is estimated to be 137,000 tons per year or about 45,000 tons per year in excess of total refinery capability in Port Colborne, Ontario and Clydach of 127,000 tons per year.

Chapter 4 World Inventories of Primary (Refined) Nickel Metal Ready for Sale

ENORMOUS STOCKS OF NICKEL ARE OVERHANGING THE MARKET

1) American Metal Market estimated the total stocks of primary nickel held by producers, merchants and consumers (at end-1976), as equivalent to 9 to 10 months of current consumption. (Charter Consolidated said about 7 months.) 7 to 8 months supply in the Western World would represent an inventory of up to *300,000 tons* of nickel at end-1977; (Falconbridge estimate it at 340,000 tons).

2) Total world stocks rose by an estimated 115,000 metric tons during 1975 and by 55,000 tons in 1976.

3) *INCO REVEALED IN NOVEMBER, 1977 THAT ITS STOCKS OF NICKEL WERE ABOUT 140,000 METRIC TONS,* OR THREE TIMES THE NORMAL LEVEL, AND AT THE END OF 1977 THE FINISHED NICKEL INVENTORY STOOD AT 154,000 TONS, ESTIMATED.

4) Consumer stocks of primary nickel in the U.S.A. alone already stood at 55,000 metric tons at the close of 1975. From a level of 23,446 tons at end-1976, stocks rose to 28,374 tons in Feb., 1977 and fell to 17,735 tons by Sept. 30, 1977.

5) WORLD MINE PRODUCTION OF NICKEL GREATLY EXCEEDED CONSUMPTION IN 1975, 1976 AND IN 1977. INCO'S 1977 OUTPUT OF NICKEL WORLDWIDE OF AROUND 191,000 METRIC TONS WAS ABOUT 10 PER CENT (23,000 TONS) *LESS* THAN IN 1976; 1978 OUTPUT, SHOULD BE ABOUT 15 PER CENT (ALMOST 30,000 TONS) *LESS* THAN 1977.

6) It may take another *two, three* or even *four* years to work off the current (early 1978) surplus inventories of finished nickel in the world, always provided that the next upsurge in capital spending on new plant and equipment rises as much as some expect. Amax, U.S.A., project that Western World 1978 nickel consumption will return to the record 1974 level of 562,000 metric tons, *but* this will *not* exceed expected Western mine output and Soviet sales by much, if at all.

4.1 Producer Stockpiles of Finished Nickel Ready for Sale

There is incomplete data on this subject. The following review covers part of the picture. In INCO LTD.'s prospectus of November 4, 1977, the company estimates that about 190,000 metric tons of nickel were added to the inventories of all producers from January 1975 to the end of June, 1977. INCO concluded that in 1975 some 109,000 metric tons of nickel went into producers' inventories as a result of the supply demand imbalance. In 1976, a total of 45,000 metric tons was added to "producers'" inventories and in the first half of 1977 another 36,000 metric tons, for a total of 190,000 metric tons added over the period 1975 through to June 1977.

Absolute levels of producers inventories at the end of 1974 were not given but if one were to assume say 3 months supply (138,000 metric tons), it could be estimated that about 328,000 metric tons were in producer inventories as of June 30, 1977.

In the 33 months from January 1, 1975 to September 30, 1977, INCO alone added 109,000 metric tons. It is estimated that at November 1, 1977, INCO had about 140,000 metric tons of finished nickel on hand. This is a credible estimate, considering the fact that the company's dollar value of all product in inventory increased from $880 million on June 30, 1976 to $1,035 million one year later. The carrying cost on this would exceed $100 million per year at 10% per annum interest, which would be greater than the current level of annual earnings for the company. (Third quarter 1977 earnings of $21.6 million if annualized, would amount to $86.4 million. However, the company's annual interest charges for all debt is still under $68 million.)

The French SLN company of New Caledonia reduced its nickel output to about 70 per cent early in 1977 and stated in the fall of 1977 that it would not increase its stocks in 1978 above the level already reached, which appeared to be equivalent to about six months' output.

Falconbridge's inventories of all metals and supplies,

end-June, 1977:	$125.2 million
1 year before:	$ 44.3 million

Falconbridge Nickel Mines has seldom carried excessive stocks of nickel. However, from December 31, 1974 to September 30, 1977 total inventories of metals and supplies increased by $81.2 million, most of which would presumably be primary metal. Assuming that 70% of the June, 1977 inventory nickel at an inventory value of $2.00 per pound, this company would appear to have had about 20,000 metric tons of primary nickel in inventory. Falconbridge revealed that its end-1977 nickel inventories were 33,000 metric tons of nickel.

The French Societe Metallurgique le Nickel (SLN), with mines in New Caledonia, had an inventory value of Ff 1090.644 million as at December 31, 1976, virtually all of which should be nickel as ferro and refined. Based upon an estimate of 40,000 tons of nickel in inventories at December 31, 1975, plus published value increases in total inventories, it can be estimated that SLN had 45-50,000 metric tons in inventories at the end of 1976. Owing to the fact that this company cut production to 62,000 tons in 1976 versus 71,000 in 1975, it appears safe to assume that little was added to inventories in 1977.

The above three companies probably represent about 210,000 metric tons of finished nickel towards the end of 1977, leaving approximately 118,000 tons in other producers' hands. Of this, perhaps 25,000 metric tons would be held by Japanese refiners, mainly in the form of ferro. The remaining 93,000 is likely to be largely held by Western Mining, Sherritt Gordon, Amax, Freeport, and South African producers.

4.2 Consumer Stockpiles

In section 2.1.6 reference was made to the level of finished nickel in consumer stocks relative to consumption in the U.S.A. and it was indicated that a normal level (as a per cent of annual consumption) is about 15%, i.e. about 8 weeks' supply. As of the end of August, 1977, this percentage fell to 12%. In West Germany, refined nickel stocks at consumer plants rose to about 33% of mid-1977 domestic consumption rate, while in the U.K. production, export and import statistics suggest that a level of some 25% of consumption is in consumer inventories. In Japan, consumers were holding about 15% of annual consumption. The weighted average of this group of countries suggests that in the Western World about 17%, or 84,000 metric tons, is now held by consumers.

4.3 Government and Intergovernmental Stockpiles

NEW UNOFFICIAL U.S. G.S.A. STOCKPILE GOALS (revealed October 1, 1976)

(not yet authorized by the U.S. Congress)

The U.S.A. receives most of its nickel *overland* from Canada with *no ocean risk*. However, Canada is no longer regarded by certain U.S. interests as a completely reliable source of nickel.

Quantity "Needed" by U.S.A.

Nickel 204,000 short tons.

"Cost" to Purchase this Quantity

Up to $1 billion (Canadian)

The goal for nickel was reduced from 55,000 tons to zero in 1971 and the nickel was sold in 1972. *There is no nickel in the U.S. stockpile at present.* Canada could be one of the sources to fill part of the above need. The launching of such procurements would probably tend to force up the price of nickel.

INCO and Falconbridge, with their very large inventories of finished nickel, (and therefore Ontario), might benefit from such a program, to a limited extent.

It does not appear likely at this time that Congress will approve this program. The Congress could argue that if INCO alone has an inventory of about 140,000 metric tons of saleable nickel, (in effect a stockpile), why should the U.S. Congress pay money for that quantity to do the same job, when it is available to the U.S.A. and *overland* at that.

STOCKPILE — FRANCE

France has a stockpile plan to accumulate 10,000 tons of nickel in ferro-nickel in five years.

OTHER COUNTRIES

No details available, but it may be considered a reasonable assumption that the Soviet Union has a large stock of unsold nickel cathodes.

OTHER U.S. GOVERNMENT ACTIONS

U.S. Commodity Policy — International

U.S. government overall policy on internationally traded commodities, both food and minerals such as nickel, appears to be concerned with two areas which are not unrelated:

1) Co-operation on a mineral by mineral basis with both producing and consuming countries to try to avoid disruptive price swings.

2) A build-up of adequate U.S. domestic stocks for strategic and/or economic purposes.

   President Carter's government indicates willingness to consider stabilization agreements on a number of minerals, etc. Discussions on the various ways of doing this will continue at UNCTAD etc., but we do not expect agreements to be concluded on any mineral in the next two years or so.

   In any case, the chances of any significant U.S. government involvement in a proliferation of international commodity "buffer stock" agreements would seem to be very slim.

The U.S. government helped to build up part of the Canadian nickel industry from the first U.S. defence contracts with Ontario nickel mines at the turn of the century through to the stockpile contracts of the 1950's and is capable of helping to dismantle part of it in the future by:

i) endorsing an image of Canada as an unreliable source of nickel. A stream of papers on this new theme has been circulating in Washington, D.C. during the last year or so.

ii) The U.S. Department of Interior, Bureau of Mines, and other government agencies, could promote and pursue a policy of preferential purchases by U.S. industry from developing nations.

iii) Ratification by Congress of: Sea Bed Nickel legislation permitting ocean mining and possibly even subsidizing the U.S. companies involved.

The irony in this possible scenario of developments is that Canada, (i.e. Ontario and Manitoba), is still the friendliest and safest source of nickel supply for the U.S.A. — and available *overland* at that. THE SIZE AND POWER OF THE SOVIET SUBMARINE FLEET IS SUCH THAT IT MUST BE REGARDED AS A DEFINITE THREAT TO THE *SEA-BORNE COMMERCE OF THE WEST.*

Fortunately, nickel and other metals can come OVERLAND from Canada. (Most of the primary *nickel* consumed in the United States is converted or melted in the *Eastern* States.)

Chapter 5 Properties of Refined Nickel Metal

Nickel is a soft silvery-white metal that is resistant to corrosion in the atmosphere and many corrosive media. It has good ductility and malleability and can be readily polished. Polished nickel has the ability to reflect a large percentage of light incident upon it. Nickel is ferro magnetic at ordinary temperatures.

Physical Properties of Nickel

Atomic Number	28
Atomic Weight	58.71
Atomic Radius	1.24 A°
Structure Type	Face-centred cubic
Lattice Constant	a = 3.5238 A°; at 20° C

Stable Isotopes

Isotope	% Abundance
58 Ni	67.8
50 Ni	26.2
61 Ni	1.25
62 Ni	3.66
64 Ni	1.16

Radioactive Isotopes

Isotope	Radioactive Decay	Half-Life
56 Ni	E.C., γ	6.4 days
57 Ni	β+, γ, E.C.	36.4 hours
59 Ni	E.C.	8×10^4 years
63 Ni	β-	125 years
65 Ni	β-, γ	2.56 years
66 Ni	β-	55 hours

Density	8.902 gm/cm^3 at 25° C
Melting Point	1453° C
Boiling Point	2730° C
Vapour Pressure	3.52×10^4 mm; at 1310° C
Heat of Sublimation	101.64 Kcal; at 0° C
Thermal Expansion	0.0000133 millionths/° C; at 25-100° C
Thermal Conductivity	0.22 cal. sec cm^2 °C/cm; at 20° C
Thermal Neutron Absorption Cross-Section	4.6 barns atom
Specific Heat	0.1125 cal/g/°C; at 100° C
Latent Heat of Fusion	73.8 cal/g
Latent Heat of Vaporization	91.0 kcal/g-atom
Electrical Resistivity	6.84 microhm-cm; at 20° C
Curie Point	353° C

Chemical Properties of Nickel

Reducing conditions usually retard corrosion of nickel, while oxidizing conditions accelerate corrosion. However, nickel has the ability to protect itself against certain forms of attack by the development of a corrosion-resisting or passive oxide film.

Outdoors, the rate of corrosion varies with atmospheric conditions; the rate is usually less than 0.0001. Marine atmospheres are scarcely more corrosive than suburban or rural atmospheres. Nickel is free from season cracking and other forms of stress corrosion in atmospheric exposure.

Nickel is highly resistant to corrosion by waters, such as distilled water, natural waters (including those containing hydrogen sulfide or free carbon dioxide) and sea water.

Nickel resists corrosion by neutral and alkaline salt solutions, with rates usually less than 0.005 ipy. Non-oxidizing acid salts are only moderately corrosive, with rates seldom higher than 0.002 ipy. Oxidizing acid salts, such as ferric chloride, and mixtures of oxidizing salts with mineral acids, are likely to corrode nickel severely.

Nickel is fairly resistant to sulphuric acid in concentrations of less than 80%. Nickel is rarely useful in contact with hot sulphuric acid solutions in concentrations greater than about 15%. With cold hydrochloric (muriatic) acid, the rates of attack vary, from 0.01 to 0.08 ipy in concentrated acid.

Nickel is not corroded appreciably by chlorinated solvents or mixtures of these with water. Nickel is corroded strongly by sulphurous acid, except the very dilute solutions used to preserve foods. Strongly oxidizing acids, such as nitric, corrode nickel rapidly.

Organic acids are only moderately corrosive to nickel. Nickel resists corrosion by the strongest alkalis.

No dry gases are actively corrosive to nickel at atmospheric temperature. Nitric oxide, chlorine and other halogens, sulfur dioxide, and ammonia are appreciably corrosive when mixed with water or condensed water vapor. Nickel is resistant to chlorine, hydrogen chloride, fluorine and hydrogen fluoride at temperatures up to about 1000F.

In a fine-grained, powdered form, nickel will absorb up to seventeen times its own volume in hydrogen, giving it certain catalytic powers. Nickel will burn at high temperatures in atmospheres of oxygen, chlorine, bromine or sulphur, but is not oxidized by either dry or moist air at normal temperatures.

Oxidation States

Nickel, in its ionic form, usually has an oxidation state of 2, although unstable states of 1 and 3 are known. The toxic compound, the gas nickel carbonyl, has an oxidation state of zero. Some standard oxidation-reduction potentials are shown below:

Reaction	V
$Ni^- - Ni^{++} + 2e$	$E^\circ = 0.250$
$Ni - 2\,0H^- = Ni(OH)2 + 2e^-$	$E^\circ = 0.72$
$Ni + 6NH_3(ag) - Ni(NH_3)_6^{++} + 2e^-$	$E^{\circ B} = 0.49$
$Ni(CN)_4 = Ni(CN_4)^- + e^-$	$E^\circ = 0.82$
$Ni + CO_3 = NiCO_3 + 2e^-$	$E^\circ = 0.45$
$S^- + Ni = NiS(\alpha) + 2e^-$	$E^\circ = 0.83$
$S^- + Ni = NiS(\alpha) + 2e^-$	$E^\circ = 1.04$
$s(OH)^- + Ni(OH)_2 = Ni0_2 + 2H_20 + 2c^-$	$E^\circ = -0.49$
$2H_20 + Ni^{++} + Ni0_2 + 4H^+ + 2e^-$	$E^{\circ B} = -1.68$
$4H_20 + Ni^{++} = +8H^+ + 4e^-$	[illegible] -1.80

(Lewis et al, 1966)

Metals Hand Book, American Society of Metals, Volume 1.

Chapter 6 Nickel Alloys Production

INCO's Deliveries from its two wholly-owned Nickel Alloy Rolling Mills (at Huntington, West Virginia and "Wiggin" at Hereford, England):

excludes Daniel Doncaster and Sons Ltd., England, acquired August 17, 1975.

	Year ended December 31					9 months ended September 30	
	1972	1973	1974	1975	1976	1976	1977
Net Sales (million U.S. $)	199.930	227.127	297.784	343.656	303.958	222.618	224.363
Gross Weight, formed metal products, approximately (metric tons)	42,640	45,900	51,700	46,700	41,200		
Nickel contained in formed metal products, approximately (metric tons)	26,300	29,200	33,580	29,960	25,400	18,400	17,700

INCO's new $25 million strip mill at Sudbury, Ontario, is expected to be completed by early 1978.

Foundry Addition Alloys

Nickel shot and in particular INCO F Nickel shot (a low melting point alloy of 92% nickel, silicon, and carbon) is used as alloy additions to cast irons in the melt for the purpose of promoting pearlite micro-structure thereby increasing the strength of the material.

About 1948, INCO announced the discovery of Ductile Iron, also known as S. G. Iron, (Spheroidal Graphite Iron), in Europe, and commenced licensing of foundries to use the process. The basic discovery was the knowledge that through reducing sulphur to low levels graphite formed in the cast iron as nodules, as compared to flakes in the iron matrix thereby raising the strength by 3 to 4 times regular cast iron. The *Incomag alloys #1 to #4 containing various contents of magnesium, silicon, carbon and nickel were developed to facilitate the necessary magnesium addition required to remove the sulphur.

Other alloys of magnesium or cereium containing iron, and silicon were developed by ferro alloy producers which compete with the Incomag alloys.

*Incocal nickel-calcium alloy 10 was developed recently containing 6% calcium, low impurities and the balance nickel. The alloy is used in steel and nickel base alloys as a final addition to remove impurities and enhance high temperature properties. Incomag and Incocal are produced in Port Colborne and Clydach refineries.

There are many custom ingot producers supplying stainless and non ferrous nickel containing ingots for use in foundries. The nickel is partly obtained from scrap monel, high nickel alloys and stainless steel alloys with final nickel content made up by additions of electrolytic cathode.

Chapter 7 Nickel Price Structure and Behaviour

PRICE: (MAINLY DETERMINED IN U.S. CURRENCY)

HISTORICAL

The reason the producers' price for nickel has historically been lower and more stable than the free market or dealers' price rested on the willingness of the major producers to lend stability and reliability to the market and to protect nickel from the inroads of competitive metals and materials.

Nickel at the producers' price was usually only made available to bona fide "users" and to certain dealers on a direct contractual basis. Very little producer price metal entered into commercial trading channels, except in periods of liquidating inventories of finished primary metal.

In the period 1951-1976, the published producers' price rose from 56.5 U.S. cents to U.S. $2.41 per pound, (U.S. $5,290 per metric ton), effective October 1, 1976 for Class I nickel, (the main nickel product of Ontario and Manitoba). Class II nickel sells at a lower price.

From October, 1970 the producers' price for electrolytic Class I nickel was U.S. $1.33 per pound. The price had previously been 85¼¢ per pound from November 1966 to September 1967, 94¢ per pound from September 1967 to December 1968, $1.03 per pound from December 1968 to November 1969, and $1.28 per pound from November 1969 to October 1970.

During 1974 alone, the producers' price rose 31 per cent from the January 1st level of U.S. $1.53 to the December 31st level of U.S. $2.01 per pound.

In July, 1977, *INCO rescinded the nickel price rises* of 9.5 per cent which it had implemented on October 1, 1976. Aggressive pricing policies by other producers are continuing. In September, 1977, nickel was still being offered at down to *$1.80 per pound,* according to Impala. INCO offering prices may now be: Class I, U.S. $2.08; Class II, U.S.- $2.00 per pound. Heavy *discounting,* (some at around 50 cents per pound below the peak producers' price of U.S. $2.41 per pound), continued in 1977 and early 1978 owing to poor nickel consumption levels.

Late in November, 1977, three producers, the French SLN company, Western Mining of Australia and Falconbridge separately posted nickel price changes. Falconbridge published nickel electro cathodes at U.S. $2.08 a pound delivered, firm through the first quarter, 1978.

PRICE — GENERAL COMMODITY OUTLOOK

Pick up in demand for commodities will be slowest for copper, nickel and wheat, which have the largest accumulations of inventories ready for sale overhanging world markets as 1978 opens. IT WILL TAKE A VERY LONG TIME TO RUN DOWN THESE STOCKS.

Generally speaking, the present outlook for food and other perishable commodity prices is much better than that for base metals, with the exception of uranium and tin and the precious metals, gold, platinum, silver, etc.

CATHODE PRICES

The standard from which all nickel prices are based is the f.o.b. refinery price for electrolytic nickel, specifically nickel cathodes. As with most metals, other producers "freight equalize" their f.o.b. price to remain competitive with the dominant producer or price leader.

Canada began producing nickel in 1888 and by 1903 this production had become significant enough to stabilize cathode prices at 40 cents U.S. per pound. The business recession of 1921 precipitated a drop to less than half this level, thus breaking an eighteen year period of very stable prices. During that time in 1917, INCO constructed its refinery at Port Colborne, Ontario but production was not significant until the early 1920's. By 1926, Port Colborne's output was slightly over 4 million pounds (versus Clydach's 19 million pound rate in 1925), but in 1929 this facility had clearly established its dominance with a 47 million pound refined nickel production, and this locale soon became the new price point (simultaneous to the merger between INCO and Mond).

During the early 1920's, cathode prices recovered to the 35 cents per pound level (by 1926) and remained steadfast for 21 consecutive years. By 1947, Port Colborne had become firmly established as the international pricing point and the price history to the present is given in the chart which follows. Also shown in this chart are the electrolytic nickel price deflated by the Index of International Inflation, an index which is calculated by the World Bank based upon the developed countries c.i.f. index of U.S. dollar prices of manufactured exports to all destinations. This index, therefore, includes considerations of both inflation and currency depreciation and the corresponding deflated nickel prices indicate a sharp decline in real terms since 1970.

The decline depicted is based on published prices. If the current level of realizations were plotted, the effect would have been many times more dramatic.

OXIDE PRICES

Nickel is available on world markets as a "sinter oxide" having a nickel content which ranges between 75 and 90% with virtually all of the commercial transactions being designated sinter 75 or sinter 90. The principal world producers are INCO Ltd., Cuba and the Greenvale, Australia joint venture.

INCO has provided the most consistent "posting" of prices and these are given below for selected years. This list price was suspended in August 1977 along with other INCO nickel products. However the CIF Europe price of Cuba's sinter 90 and sinter 76 was listed as $1.98 and $1.92 respectively, as of October 1, 1977.

Comparison of Nickel Oxide and Cathode Prices Selected Years 1965-77

	1965	1967	1970	1971	1975	1977
		($U.S. per pound)*				
INCO oxide Prices						
Sinter 75	n.a.	0.81	1.22	1.27	1.88	2.27
Sinter 90	n.a.	0.8125	1.23	1.28	n.a.	n.a.
Sinter (unspecified nickel content)	0.7525+					
	1965	1967	1970	1971	1975	1977
		($U.S. per pound)*				
INCO Cathode	0.79	.8525	1.28	1.33	2.01	2.41
% discount on Sinter 75	5	5	5	5	6	6

\+ includes 1¼ cents import duty
* January unless otherwise noted, CIF point of entry, nickel content
n.a. not available

Source: Canadian Minerals Yearbook, selected issues, Department of Energy, Mines and Resources.

It can be seen that sinter oxide carries a discount of 5 - 6% on nickel content. Falconbridge nickel has recently, (November, 1977), began posting prices and it now places a list price of $2.08 U.S. per pound of electrolytic nickel on a delivered basis. This would suggest that present oxide prices are in the order of $1.95 per pound on a similar delivered basis.

FERRONICKEL PRICES

Ferronickel has been traditionally sold on the basis of contained nickel content (usually 40% of total weight) with no charge being made for the iron content. Recent prices of SLN ferronickel are given below, for three common grades. In general ferronickel can be purchased with grades of nickel content ranging from 20 to 50 per cent, carbon 1.5 - 1.8%, cobalt 1 - 2% (included with nickel), silicon 1.8 - 4% and chromium 1.2 - 1.8% with iron taking the balance.

Recent Ferronickel Prices*

	1974	1975	1976	1977
		($U.S. per pound)		
SLN Grades				
FN – 3	1.99+	2.19	2.39	2.07
FN – C	1.97	2.17	2.37	2.05
FN – 4	1.95+	2.15	2.35	2.03

* Ex dock, Baltimore, U.S.A.
\+ Estimated

Effective Dates: December 12, 1977
October 1, 1976
October 9, 1975
December 20, 1974

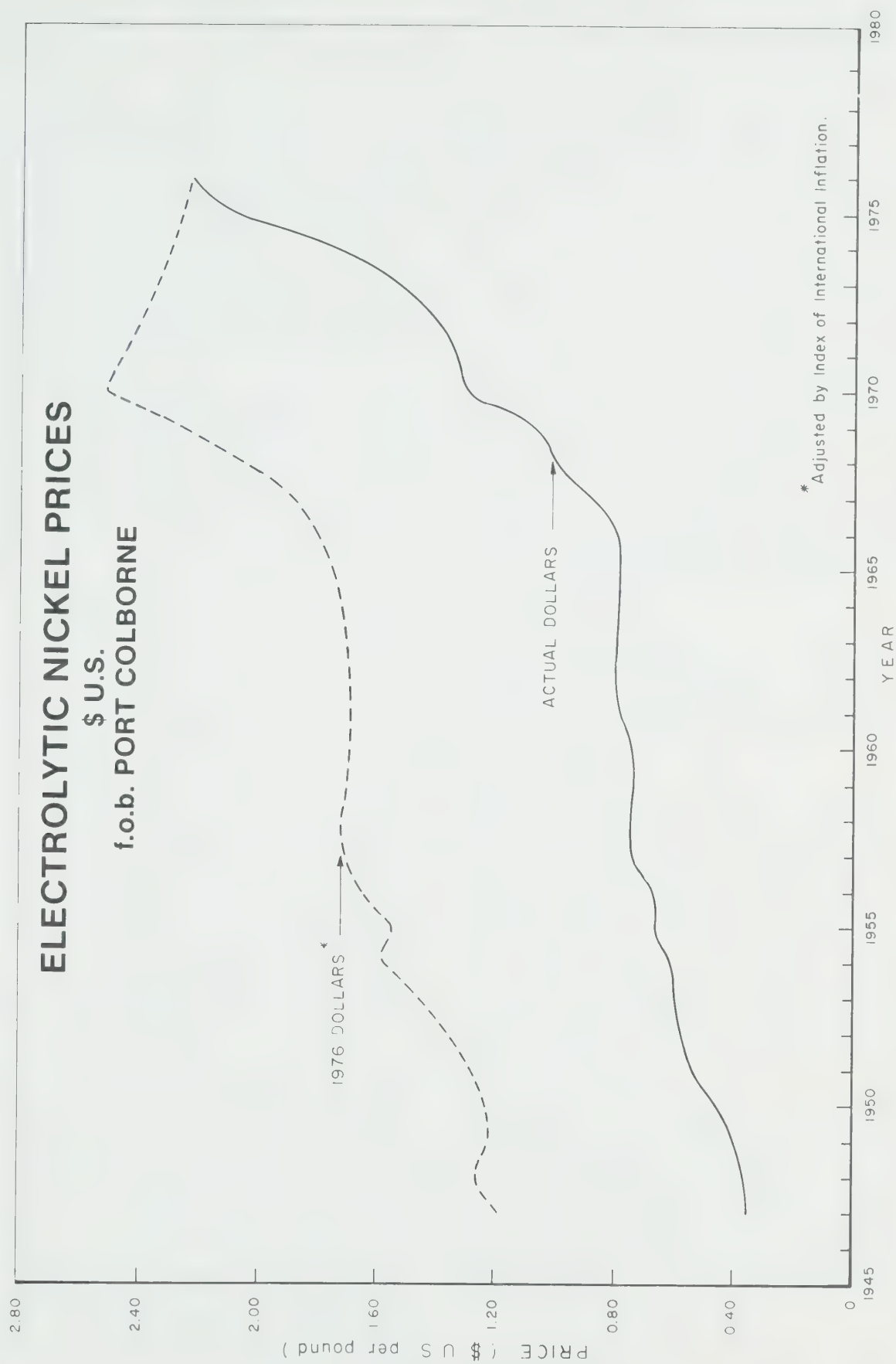
Sources: American Metal Market, E/MJ, Metals Week.

Owing to the many different pricing bases in the nickel industry, it is difficult to make an accurate assessment of the premium paid for cathode nickel over ferronickel. However, Metal Bulletin publishes SLN's delivered price for refined nickel into France and also SLN's FN – C price CIF U.K. port. As of September 1, 1977, the difference was $0.13 per pound, i.e. 6% discount.

On November 30, 1977, Falconbridge Nickel broke tradition and began charging 2.5 cents per pound iron content, thus eliminating one form of discounting. The nickel content was set at $2.00 per pound of nickel content and at 60% iron content, this would have been a discount of about 2%. As it now stands, Falconbridge charges a premium of $0.08 for cathode nickel (Grade A), relative to their own ferro-nickel.

METAL EXCHANGES

Nickel is not traded on any public metals futures exchange, but from time to time there is talk of a nickel contract being introduced in New York.


ELECTROLYTIC NICKEL PRICES
$ U.S.
f.o.b. PORT COLBORNE
1976 DOLLARS*
ACTUAL DOLLARS
*Adjusted by Index of International Inflation.
PRICE ($ U.S. per pound)
YEAR
2.80
2.40
2.00
1.60
1.20
0.80
0.40
0
1945
1950
1955
1960
1965
1970
1975
1980

Chapter 8 Financial Structure and Developments

8.1 Financial Structure of the Nickel Producing Industry

From the chart which follows, it can be seen how the three Canadian nickel producers are connected by equity ownership to other world producers. Of the three companies, only INCO Ltd. is management controlled since Newmont Mining Corporation, U.S.A. has a substantial interest (about 39.7%) in Sherritt Gordon Mines Ltd., and Superior Oil, U.S.A. has effective control over Falconbridge Nickel Mines. All three Canadian producers of nickel have minor equity interests in overseas nickel projects, and the two Ontario producers have control over production in Guatemala, Dominican Republic, Indonesia and Norway.

Because nickel is a relatively new metal it seems inevitable that from time to time one or more new producers would have a noticeable impact on world production. During the embryonic years of the industry, New Caledonia became the prime producing area, predominately Societe Le Nickel (SLN), together with other firms which later merged with it. By the end of the early 1900's, however, INCO's predecessor companies were providing fierce competition to SLN, eventually overtaking it as world leader.

While INCO is generally thought of as being a Canadian producer, two of its predecessor companies (Nickel Corporation and Societe Miniere Caledonienne), had substantial interests in the island of New Caledonia. The laterite deposits of these two corporations were eventually absorbed in the merger of SLN's predecessor companies in the early to mid 1920's, and INCO's formal links with New Caledonia production were ended at about that time. Subsequently, SLN remained a French company. Similarly, International Nickel had become close to several American corporations, particularly U.S. Steel Corporation, which provided much of its initial financing. While INCO is said to be management controlled, it is generally accepted that the French Rothschild interests effectively operate SLN through a recently formed holding company called Imetal S.A.

In the late 1920's Falconbridge Nickel Mines was incorporated and control held by Ventures Limited. The subsidiaries of this corporation and their financial structure were reorganized with Ventures being taken over by Falconbridge during the early 1960's. Control of Falconbridge was later purchased by McIntyre Mines, and subsequently the Keck interests of Texas (via Superior Oil) took control of McIntyre Mines.

Prior to the expropriation in 1959 by the Castro regime in Cuba, Freeport Minerals, U.S.A. had control of Moa Bay and several other laterite deposits. After this expropriation, the Freeport Minerals group was out of the nickel business until they initiated their Greenvale project in Australia in the 1970's. Greenvale is also a lateritic producer and Metals Exploration Limited is a partner in this venture which came on stream in 1975. In the early 1970's, the U.S. Amax group purchased and reconstructed the Port Nickel Refinery in Louisiana, U.S.A. At the same time an affiliated company, Selection Trust Limited, was developing Australian interests. RST International (a wholly owned subsidiary of Amax) developed the Botswana RST Limited mine in partnership with the Anglo-American and Charter Consolidated groups. Selection Trust now has a minority interest in Western Mining, Australia, which now owns Great Boulder Mines. It also controls (through Consolidated Africa Trust and Selcast Holdings), Selcast Exploration which is a partner in the Agnew project in Australia.

INCO has a major interest in Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal) of Guatemala, a laterite development, and its partner in that project is Hanna Mining, which is controlled by National Steel, U.S.A.

INCO Limited has South African connections as well, namely a 10% holding in Impala Platinum. Control of this latter company is via Union Corp. and UC Investments, with Hambro's Bank of London also having a substantial interest. Falconbridge holds 24.5 per cent of Western Platinum, a South African mine producer of platinum and nickel.

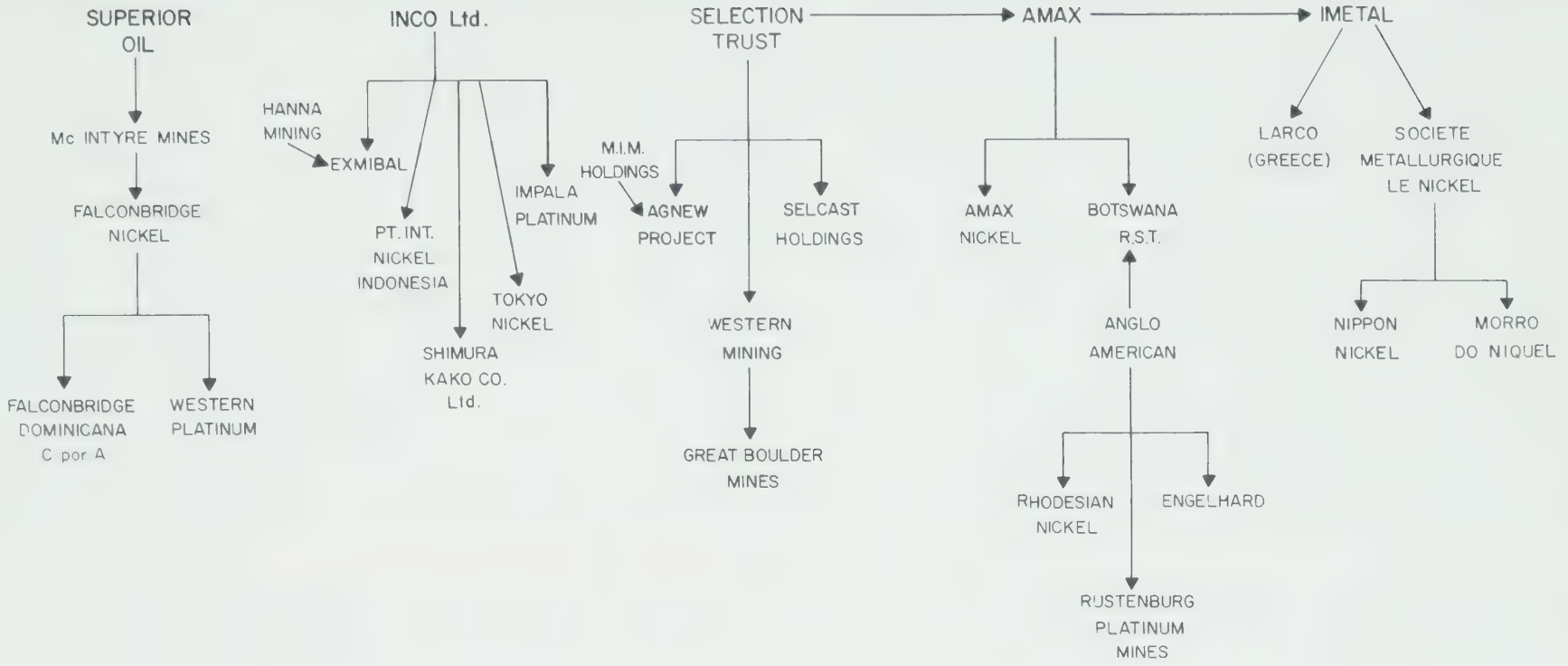
Looking at South Africa, the Anglo-American Corporation of South Africa Group has control over one of the principal Rhodesian nickel producers, Rhodesia Nickel Corporation Limited, and also part control of Rustenburg Platinum Mines, along with its affiliate Engelhard, a major platinum group metals, gold and silver refining and fabricating group based in the U.S.A.

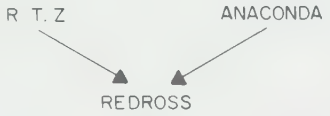
In recent years the Imetal group, via SLN, has taken an interest in Morro do Niquel in Brazil and indirectly, through Societe Metallurgique de Penarroya, an interest in Larco of Greece. Through a related corporation, Rio Tinto Zinc and its subsidiary Conzinc Rio Tinto of Australia, the British Rothschild interests have a joint venture with Anaconda, the Redross mine in Australia.

Much of the recent activity in the nickel exploration and development area has been centered around Indonesia and in New Caledonia. For instance, PT Pacific Nikkel Indonesia is a joint venture of U.S. Steel, Hoogovens Steel, Mining Corporation and Amoco Minerals (Rockefeller interests). INCO also has a major project which recently came on stream in Indonesia — INCO's PT International Nickel Indonesia.

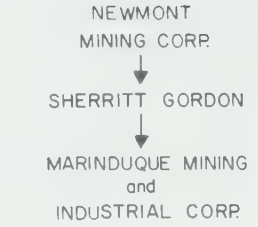
The French Government agency, Bureau de Recherches Geologiques et Minieres (BRGM) has been involved in a number of New Caledonia projects. One joint venture is a Goro prospect in which INCO may be assisting BRGM. Other venture projects are with Amax, and also with Granges of Sweden and the French steel and nonferrous metals producer, Pechiney-Ugine-Kuhlmann.

It should therefore be apparent to the reader that the world nickel industry is a very complicated one in financial structure, fabric and the inter-relationships with the consumers. It is therefore perhaps one of the most difficult industries for a newcomer to enter and capture a market share, considering these many connections between producing and consuming companies. The problem of capturing a market share would also be compounded by the fact that nickel has never been in a real long term shortage situation. Most consumer requirements are likely to be adequately met by existing connections.

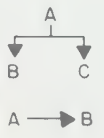








ESSENTIAL FINANCIAL TIES OF NICKEL PRODUCING INDUSTRY — 1977



LEGEND

OWNERSHIP (⩾ 10 %) OF LARGER CO.
A in B & C
A OWNS ⩾10 % OF B'S EQUITY
DIRECT & INDIRECT

8.2 Nickel Refining Plants

ROASTING

Generally sulphide ores are subjected to roasting, smelting and converting, subsequent to the production of nickel-copper sulphide concentrates, and prior to refining to pure nickel.

Roasting is the first step in which some of the sulphur is driven off and the iron is oxidized. The process carried out in multiple hearth roasters (Inco, Copper Cliff Smelter) which are cylindrical furnaces in which the concentrate slowly passes down from the top hearth to a lower hearth while being heated by rising gases. The iron sulphides finally burn and the resultant product is ready for smelting.

Sintering machines are used for roasting in conjunction with blast furnace smelting of nickel concentrates. In essence, it is a travelling grate on which the material travels while roasting. The feed to the sinter machine is pelletized before entering the roaster.

Fluid bed roasters are a newer innovation utilizing air blown through a bottom grate which holds the particles in suspension. Roasting is very rapid and the roaster handles large volumes of feed. Inco operates a fluid bed roaster at Thompson, Manitoba.

Inco, Copper Cliff also incorporates a kiln in the Iron Ore Recovery Plant to reduce iron nickel calcine prior to separation of nickel and copper (from the magnetite) by leaching.

SMELTING

SULPHIDE ORE SMELTING

The second step in the process of separating nickel or nickel and copper sulphides from the iron is smelting. The calcine from the roasters can be treated in several different furnaces in which silica, coke, and other fluxes are added in order to slag off the iron. The calcine becomes molten and the iron oxide combines with silica and is floated off from the top of the molten sulphides.

The process is carried out in blast furnaces; (now becoming obsolete) reverberatory furnaces where fuel may be natural gas, coal, and oxygen; and flash smelting furnaces used in Inco's Copper Smelter in Sudbury and Outokumpu's nickel smelter in Finland.

Flash smelting is an autogenous process in which the fuel roasts and smelts almost instantaneously as an exothermic reaction. Preheated air and oxygen are used and sulphur dioxide is collected from the gases for the production of sulphuric acid.

Electric furnace submerged arc smelting is a common method for treating ores, concentrates and calcines of sulphide ores. Inco, Thompson, Manitoba, employs three furnaces when operating at capacity. Falconbridge Nickel is presently installing electric furnaces. This is partly because of environmental requirements. Electric furnace smelting reduces gas volumes markedly. Major Russian sulphide ore deposits use electric furnaces at Pechenga, Monchegorsk and Noril'sk.

OXIDE ORE SMELTING

Blast Furnace Smelting is employed by SLN in the Doniambo, New Caledonia smelter where dried ore and sintered pellets are mixed with coke, gypsum, limestone and silica. The sulphur in the gypsum reacts with the iron and nickel oxides to form matte and the slag is tapped off. Sumitomo, Japan, employs a similar process incorporating sulphide concentrates. Since 1950, several variations of reduction kilns or roasters have been put in use by Pacific Metals and Sumitomo in Japan, Larco in Greece, Metals Exploration N.L., Greenvale, Queensland, Australia, P.T. International Nickel, Indonesia, Falconbridge Dominicana, Inco-Hanna, Exmibal, Guatemala.

There are also two smelters in Japan using the *Krupp-Renn* process developed in Germany in the 1930's — in which the nickel is mostly reduced to metal. Sintering machines are also used to dry and preheat ore in some Japanese smelters prior to electric furnace smelting.

Most of the kilns partially reduce the ore or use sulphur in one form or another to produce a sulphide product prior to smelting. Falconbridge Dominicana uses a vertical shaft counter-current reduction tower incorporating naphtha gas which almost completely reduces nickel and cobalt. Metals Exploration N.L., Greenvale uses ten vertical multiple hearth roasters using fuel oil to reduce the nickel and cobalt and Marinduque Mining and Industrial Corporation uses the Sherritt Gordon design suitable for oxide ores, for roasting and reduction to reduce to nickel and cobalt, prior to ammoniacal leaching recovery in the refinery.

MATTE SEPARATION — SULPHIDE ORES

Where the ores contain appreciable amounts of copper as well as nickel, matte preparation via converters must be done, where further oxidation of iron and sulphur takes place resulting in a nickel-copper sulphide matte and iron oxide slag. Converters are used at Inco Copper Cliff, Ontario, Falconbridge, Ontario, Outokumpu, Finland.

Matte separation of nickel and copper sulphides, is either done by slow cooling of matte (INCO, Copper Cliff) or roasting, followed by leaching with sulphuric acid (Outokumpu, Finland). Russian operations employ slow cooling and further beneficiation similar to INCO operations or by fluid bed roasting to oxide after matte separation. Falconbridge, Norway changed their process to hydrochloric acid leaching in the early 1970's.

REFINING PLANTS

The refining of impure nickel is carried out in order to remove impurities which would de deleterious if they become constituents in the final intermediate product produced (steel, super alloy or other non-ferrous alloys). Refining is also done to recover other marketable metals such as cobalt, precious metals.

ELECTROLYTIC REFINING

Crude nickel anodes are made by further processing nickel matte which is reduced to nickel oxide by fluid bed roasting or by multi-hearth roasting. The oxide is then further reduced to crude nickel and cast as anodes either by reduction in reverberatory furnaces with coke or electric arc furnace with coke. Inco, Port Colborne, Ontario reduces nickel oxide from Copper Cliff in reverberatory furnaces.

Sumitomo, Japan also cast anodes after reduction melting in electric furnaces. The feed is 70:30 oxide-sulphide mix of concentrates and matte from New Caledonia and Inco, Canada.

It is believed Russian refineries at Monchegorsk and Noril'sk use similar processes to Inco at Port Colborne, Ontario.

Electrorefining is basically an electrolytic cell in which the impure nickel anode and a thin pure nickel cathode are placed in an electrolyte. The anode and cathode are connected through direct current and the electrolyte conducts the flow of electricity to complete the electric circuit. This is a net cell reaction in which the sum of anodic and cathodic reactions equals zero theoretically, In essence, a potential difference is created causing nickel to dissolve in the electrolyte around the anode. This solution is drawn off, purified and deposited around the cathode where the nickel is deposited on the starter sheet cathode.

ELECTROWINNING

This method of electrolytic refining results in a net cell reaction in which sulphur in nickel sulphide in the case of nickel sulphide anode is oxidized or in the case of an insoluble anode the nickel sulphate electrolyte is broken down to oxygen, sulphuric acid and nickel ions.

Inco, Thompson, Manitoba uses nickel sulphide anodes, whereas Outokumpu, Finland, uses insoluble lead anodes. The use of nickel sulphide anodes in Thompson, Manitoba bypasses roasting and reducing operations and of course matte separation because copper content is low in the concentrate. Outokumpu, chose insoluble anodes because of the small production planned. Falconbridge ceased electrolytic refining in 1977 and changed to a chlorine leach and insoluble anodes.

VAPOMETALLURGICAL REFINING

The production of pure nickel by recovering the metal as a gaseous compound started commercially in 1902 at Clydach, Wales using Sudbury, Ontario ores. The refinery known as the Mond Nickel Company Ltd. named after the co-inventor of the process Ludwig Mond, became part of International Nickel group in 1929.

By the use of carbon monoxide gas in contact with crude nickel either at atmospheric or elevated pressures, nickel can be selectively removed from other metals as nickel carbonyl either as a gas or liquid. The resultant product is then reduced to nickel and carbon monoxide gas at temperatures between 300 and 600F. The final product is highly pure nickel in powder or pellet form. Inco Metals Company produces pellets and powder in the new nickel refinery in Copper Cliff, Ontario and also Clydach, Wales.

HYDROMETALLURGICAL REFINING

In the past 35 years, the extraction of nickel by chemical dissolution has become an important method of nickel recovery and also other metals of value accompanying nickel in the ores, (e.g. cobalt, copper, sulphur, precious metals). Leaching of a pretreated ore or concentrate results in selective collection as an aqueous phase of the desired metal. Ammonia and sulphuric acid are in common usage. The original plant was built in Nicaro, Cuba during World War II in which Freeport Sulphur Company used an atmospheric ammonium treatment to recover nickel. In 1959 Freeport Sulphur Company commenced pressure leaching, with sulphuric acid of Cuban oxide ores in Port Nickel, Louisiana. (This refinery was redesigned and rebuilt in 1974 by AMAX and now produces nickel from matte and concentrates, supplied from Botswana, Africa, and other sources.)

Sherritt Gordon Mines Ltd., in conjunction with Professor Forward of University of British Columbia developed pressure leaching with ammonia in which nickel and cobalt was recovered from Lynn Lake, Manitoba sulphide concentrates at Fort Saskatchewan, Alberta. The refinery now processes matte and concentrates from purchased sulphide and oxide ores. In fact, the process has been applied by Western Mining Company in Australia, Marinduque Mining and Industrial Company, Philippines and Impala Platinum, South Africa.

Metals Exploration N.L., Greenvale Project, Australia employs ammonia and ammonia carbonate to produce a 90% nickel oxide, and nickel-cobalt-sulphide from silicate-oxide ore.

Amax Nickel Refinery employs atmospheric leaching with spent sulphate electrolyte from the copper pressure leaching circuit. Nickel hydroxide method of separating cobalt and nickel (Outokumpu process) is then applied. Final products of the operation are nickel briquettes and powders, cobalt briquettes, copper cathodes (by electrowinning) and ammonium sulphate.

Falconbridge, Norway and Outokumpu, Finland employ selective leaching as part of the process prior to electro refining of the nickel.

SEA NODULES

Solvent extraction of nickel, cobalt and copper from sea nodules has already been investigated and further pilot plant work is now being done by (Inco Consortia) in the Port Colborne, Ontario pilot plant. Although there is not complete agreement among the various professional hydrometallurgical or chemical engineering groups in the world, solvent extraction can usually mean a liquid — liquid extraction process in which one liquid is aqueous and the other organic. It is the transfer of a solute from one liquid phase to another as distinct from leaching in which a liquid (aqueous or organic) is intimate with a solid (a concentrate or ores) and accepts a particular metal (e.g. nickel) into solution in the liquid.

Thus solvent extraction takes place after leaching in which the nickel, copper or cobalt now in solution as a metal salt interacts with an organic solvent and is separated from other metals in the aqueous solution (i.e. it transfers to the organic liquid phase).

Solvent extraction is already in use to separate copper and nickel, and cobalt from ores, tailings and spent liquors of metal refineries producing other metals; as well as copper, such as platinum and palladium.

There are eight plants in the United States, two in Chile, two in the United Kingdom and Japan, and others shown in the following tables including Falconbridge Nickel Refinery in Norway and Inco Copper Cliff:*

* Reference: Chemistry and Industry Volume Number 17, September 3, 1977, P. 708, 709.

TABLE 8.2

SUMMARY OF NICKEL-COBALT SOLVENT EXTRACTION PLANTS

Plant	Type of Feed	Comments
Falconbridge Nikkelverk, Norway	Chloride liquors from matte leach process plant	TBP used to extract iron, Adogen 281 used to extract Cu and Co from nickel rich liquor.
Falconbridge Nikkelverk, Norway	Dissolution of impure nickel cobalt hydroxide in HCl	Adogen 281 in Solvesso 100 used to extract cobalt. Cobalt recovered by direct electrowinning from strip chloride liquors.
Societe Le Nickel, Le Havre, France	Chloride liquors from leaching of slag produced on chlorine blowing of nickel matte	Iron extracted by LA-2 and cobalt recovered by Adogen 381 to provide pure nickel chloride electrolyte.
INCO, Copper Cliff, Canada	Sulphate liquor from leaching of IPC plant residue	Iron is removed by hydrolysis prior to cobalt extraction in columns at elevated temperature using DEHPA. Plant constructed but not yet operated.
Nippon Mining Co., Japan	Unknown	DEHPA used as extractant.
Ise Chemical Industries, Japan	Unknown	Trictylamine used as cobalt extractant so chloride liquors must be employed.
SEC Corporation, El Paso, U.S.A.	Spent electrolyte from Phelps Dodge copper refinery	Copper recovered by extraction with LIX64N and electrowinning. Raffinate rendered ammoniacal and nickel recovered by extraction with LIX64N and electrowinning.

TABLE 8.3

SUMMARY OF COPPER SOLVENT EXTRACTION PLANTS

Plant	Type of Feed	Copper Production (kg day^{-1})	Comments
Ranchers Exploration and Development Co Ltd, Bluebird Mine, Miami, Ariz, U.S.A.	Dilute H_2SO_4 leach of oxide ore	18,200	World's first copper SX plant
Bagdad Copper Corp, Bagdad, Ariz, U.S.A.	Dilute H_2SO_4 leach of oxide ore	18,200	Cathodes achieved Comex rating in August, 1975.
Cyprus Mines Corp, Johnson Camp, Ariz, U.S.A.	Dilute H_2SO_4 leach of oxide ore	13,650	Plant now on stream. Capital investment said to be $1,140/ton cathode copper. Comex rating achieved for copper cathodes.
Cities Services Co, Miami, Ariz, U.S.A.	Leach liquor from caved area of old underground mine at Miami, Ariz	13,650	Plant now on stream.
Anaconda Co, Anaconda, Montana, U.S.A	Ammoniacal leach of 25 per cent sulphide concentrate	82,000	Plant reopened late 1976-early 1977.
Anaconda Co, Twin Buttes, Ariz, U.S.A.	Dilute H_2SO_4 leach of oxide ore	90,000	First copper produced August 1975.
Duval Corporation, Battle Mountain, Nevada	Heap leach of oxide copper	140,000	A SX-EW plant using LIX64N, Construction Company, Holmes & Narver, cost $6M. Completion expected late 1978.
Kennecott, Ray Mines Division, Ariz, U.S.A.	Leach liquor from silicate ore		Pilot plant study only at present.
Mineroperu, Cerro Verde, Peru	Oxide leach	90,000	Start up originally planned for 1976. New start up date unknown.
Cerro de Pasco, Peru	Mine waters and dump leach liquors	1,500	At the planning stage.
Compania de Cobre, Chuquicamata, Chile	H_2SO_4 leach of oxide Exotica ore	100,000	Detailed engineering under way under DPG supervision. Plant construction timing dependent on finance availability.
Lo Aguirre Copper Mine, Socidad Minera Pudahuel Ltda, Chile	Acid leaching of oxide copper ore	50,000	Holmes & Narver hired to build leach – LIX — electrowin plant. Plant investment — $40M.
Nchanga Consolidated Copper Ltd, Nchanga, Zambia	Acid leach liquor from tailings leach	182,000	Plant operating very successfully. One of the four parallel streams now using SME529 for SX instead of LIX64N.
Nchanga Consolidated Copper Mines Ltd, Kansanshi Mine, Solwezi, Zambia	Acid leach of oxide copper ore	75,000	Plant delayed due to low copper price.
Societe Miniere Tenke Fungarume, Zaire	Acid leach of copper, cobalt oxide ore	250,000	Original project shelved due to lack of finance. Consideration now being given to scaled down version. (90,000t a^{-1})
Proteous Reclamation Ltd, Manchester, U.K.	Spent ammoniacal copper etchants	300	First known commercial use of Acorga P5100 reagent.

Expert opinions indicate that a major application of solvent extraction processes will take place with the extraction of nickel and cobalt from sea nodules. Two groups have already developed advanced flow sheets, Kennecott Consortium and Deep Sea Ventures. Kennecott pilot plant studies indicate a primary ammoniacal leach of the ground nodules and hydroxyoxime extractants. Deep Sea Ventures indicates a hydrochlorination primary treatment (leaching) and one alternative is then acid chloride liquors in conjunction with Kelex or LIX reagents.

The proposed flow sheets are shown below:

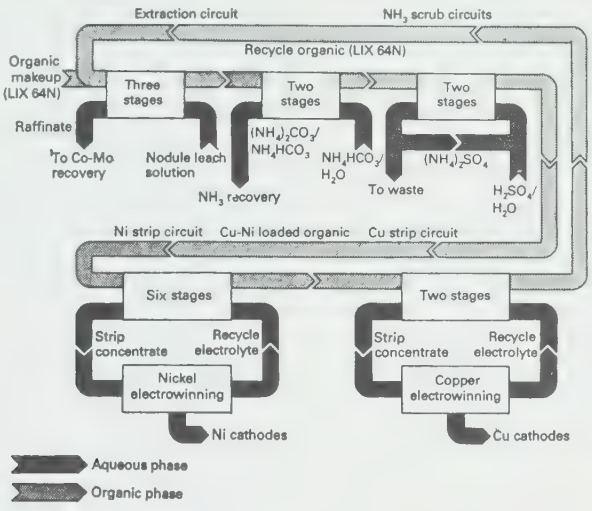


Fig. 1 Schematic flow-sheet of Kennecott's coextraction selective stripping process.

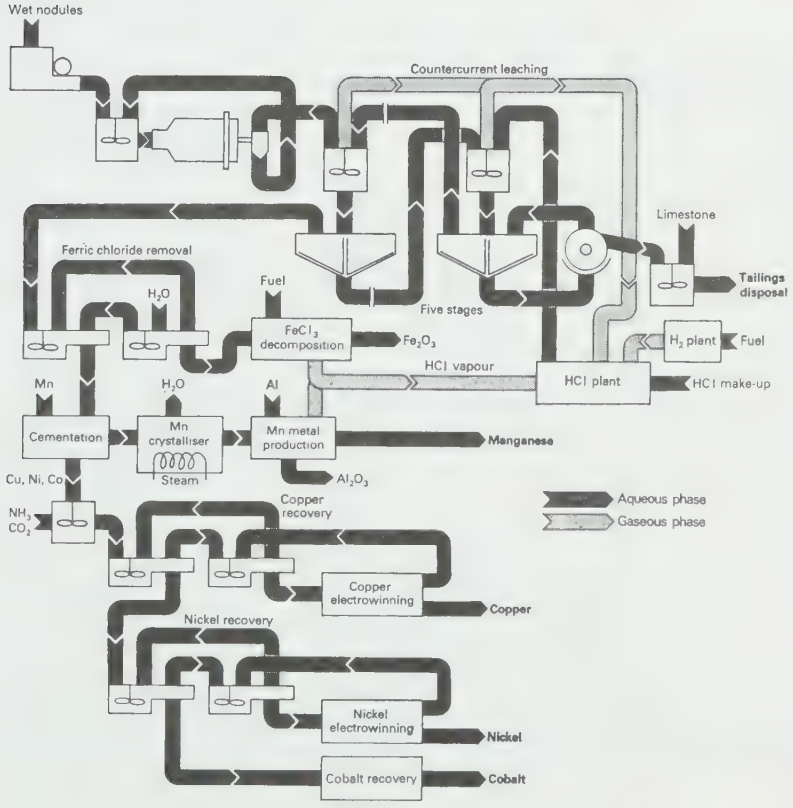


Fig 2 Hydrochloric acid process

FERRO NICKEL

Ferro nickel containing nickel from 20% to 50% and various amounts of impurities and carbon, balance iron, is produced from oxide ores. As indicated in the preceeding sections, the ore is pretreated and prereduced by various methods. The final product is melted in one or two stages in electric furnaces and/or converters in which a reducing stage is carried out first and oxidizing stage necessary to remove impurities is the completion. The ferro nickel is then poured into pigs of various sizes.

Ferro nickel which is now accepted as an important primary nickel source for alloy and stainless production is produced by Hanna Nickel Smelting Company, Riddle, Oregon; Falconbridge Dominicana, C por A, S.L.N. New Caledonia; Morro do Niquel, Brazil; Larco, Laryma, Greece; Sumitomo, Shimura Kako, Pacific Metals, Nippon Yakin, Nippon Mining, all of Japan and Yugoslavia.

NICKEL OXIDE

Nickel oxide is an intermediate product containing nickel from 75% to 90% and even up to 95%, the balance being primarily oxygen. Nickel oxide is a product of nickel refining either sulphide or oxide ores. Inco, Copper Cliff, Ontario produces Inco sinter 75 in the matte processing plant, and also "Incomet" (95% nickel) by chlorination reduction. Cuba produces 75 and 90% nickel oxides. Russia produces 76% nickel oxide in Ufaley and Orsk. Tokyo Nickel and Nippon Nickel produce 75% nickel oxides. Falconbridge, Norway produces "Nickel 98" and Metals Exploration N.L., Queensland, Australia produces 90% nickel oxide briquettes. Inco also produces a soluble nickel oxide used to produce nickel salts.

8.3 Capital Cost Smelter and Refinery Plant

Very few companies involved in development of new nickel projects in the past 10 years have identified specific values of capital expenditures for smelter and refinery construction. Infrastructure costs, including power plant which may service mining operations, smelting and refining, as well as town site electrical demands, confuse the capital cost structure. Also start-up costs, docking facilities, roads, sewage disposal plant, interest on loans, are usually included in plant and equipment costs or in development costs of a new project. The data following is derived from annual reports, reports required in prospectus, company press releases, trade magazines and local government publications.

INCO METALS COMPANY

During the 10-year period 1967 through 1976, Inco invested $635 million in smelter and refinery facility including new processes, equipment replacement and environmental requirements. Based upon present estimated capacity in Canada and the United Kingdom, the investment is equivalent to $1,427.00 per metric ton of annual capacity (254,000 metric tons of nickel plus 191,000 of copper). The new nickel refinery in Sudbury completed in 1973 required $140 million for an output of 57,000 metric tons per year or a cost of $2,460 per metric ton capacity. The expenditures do not include Indonesia and Guatemala.

FALCONBRIDGE NICKEL MINES (Integrated Nickel Operation)

From 1967 - 1976 expenditures for plant and equipment in Canada and Norway were $332 million which included process improvement, equipment replacement, and environmental requirements. The expenditures are equivalent to $4,716.00 per metric ton of 25,400 copper and 45,000 metric tons of nickel annual capacity. About $65 million was written down when the iron pellet plant was closed. Excluding the pellet plant, capital expenditure was about $3,793.00 per metric ton of capacity.

FALCONBRIDGE DOMINICANA C por A

The total outlay was about $195 million for a production capacity of 28,500 metric tons or $6,842 per ton of capacity. Expenditures were concentrated in the years 1969-1972. Smelter capital investment is not published.

WESTERN MINING CORPORATION — Australian Refinery

Capital expenditures for approximately a 13,600 metric ton refinery was about $30 million (Australian) in 1970 or $2,200(A) per metric ton yearly capacity. The plant, other than the equipment to handle finished nickel can process much higher quantities than the original 13,600 metric tons.

MARINDUQUE MINING AND INDUSTRIAL CORPORATION — Philippines

Total capital expenditures are now estimated at $290 million (U.S.) for a 34,000 metric ton of nickel plus cobalt, per year capacity. Smelting and refining capital expenditures including supporting facilities are about $200 million. Thus smelting and refining expenditures amount to $5,880 per metric ton of capacity or $8,530 per metric ton of capacity for the total facility. The plant was completed in 1975-1976.

S.L.N. — NEW CALEDONIA EXPANSION

The total expansion which is mostly process equipment and an ore handling facility for 15,000 metric ton capacity per year is estimated to be about $5 per pound of nickel produced/year or $11,000/metric ton.

P.T. INTERNATIONAL NICKEL INDONESIA

Total capital expenditures are now $875 million for 45,000 metric ton capacity equal to $19,400 per metric ton which will produce matte requiring further refining.

METALS EXPLORATION N.V. — GREENVALE PROJECT, AUSTRALIA

Total capital expenditures of $370 million to produce 24,500 metric tons or equal to $15,100/metric ton yearly capacity, of nickel oxide, 90% nickel.

EXMIBAL, GUATEMALA

The Inco-Hanna mining development capital investment is estimated to be $232 million for a matte production of 13,000 metric tons/year or about $17,850 per metric ton of capacity.

P.T. PACIFIC NICKEL, INDONESIA

The recently announced consortium including U.S. Steel, Amoco Minerals and Hoogovens plan to develop a 51,000 metric ton capacity at an estimated capital cost of $1 billion or $19,600 per metric ton of production.

B.R.G.M. — AMAX, NEW CALEDONIA

This is another very recent project announced which is estimated to require $600 million for a production of 24,000 metric tons or a cost of $25,000, metric ton capacity.

EMPRESA COLOMBIANA DE NIQUEL, COLOMBIA

Hanna Mining and Chevron Petroleum and the Colombian government announced in October 1977 a ferro nickel plant which will produce 19,000 metric tons of nickel at a cost of $300 million or $15,800 metric ton capacity. This estimate based upon a news release appears quite low compared to new projects about to be completed or launched.

NODULES

There have been estimates published in trade publications indicating a capital cost of about $22,000 per metric ton of capacity per year. It is much too early to assume the estimates are either high or low.

SUMMARY

Inco Metals total capital expenditures excluding Indonesia, Guatemala and rolling mill facilities was $1,281 million (1967-1976) actual dollars, equivalent to $2,879.00 per metric ton of nickel and copper capacity. Falconbridge invested $385 million equal to $5,469 per metric ton actual dollars of nickel copper capacity. Even if the expenditures which were spread over 10 years were converted to current dollars, the capital cost per ton would be much less than double the foregoing figures for Inco and Falconbridge. The result is considerable new mine and process plant completed and operating.

Comparing the costs per ton of Inco expenditures with new projects about to be completed and future planned projects, Inco's cost in current dollars would be only 33% to 50% per metric ton of new competitive capacity. Falconbridge's costs are equal to or as much as 50% less than new planned projects.

8.4 Planned Nickel Projects

There is an impressive list of new nickel projects either nearing completion or which have been recently announced as agreements which will commence shortly. In many cases, the projects will be producing a product which can be sold directly to the consuming industry. Some projects will produce concentrate or matte which will be sold to smelters and refineries with capacity to process to briquettes, ferro nickel, powders, electrolytic cathode, pellets and salts. The planned production is 232,000 metric tons up to 248,000 metric tons, of which sulphide ores will be about 4-6% of production.

There are many other potential projects in India, Canada, Australia, Brazil, the Philippines, the Malagy Republic, Venezuela, Greece, Indonesia and, of course, there will likely be ocean mining of nodules.

The projects approaching completion or on which agreements were recently announced are as follows:

TABLE 8.4

PLANNED NICKEL PROJECTS

Project	Product	Nickel Contained Metric Tons	Destination
P.T. International Nickel Indonesia, 1977	Oxide Ore Matte	45,000	Japan Smelters Inco, Clydach, United Kingdom
Exmibal, Guatemala (Inco-Hanna), 1978	Oxide Ore Matte	13,000	Inco, Clydach, United Kingdom Possibly Hanna, U.S.A.
Selection Trust, Australia Agnew Mine, 1979	Sulphide Ore Concentrates	10,000-15,000	Amax, U.S.A. Port Nickel, LA.
Cuba, 1980	Oxide Ores Nickel Oxide	30,000	Market
Feni, Yugoslavia, 1979	Oxide Ores Ferro Nickel	11,000	Market
Larco, Laryma, Greece, 1980	Oxide Ores Ferro Nickel	12,000	Market
S.L.N., New Caledonia, 1980	Oxide Ores Ferro Nickel Matte	15,000	Le Havre Refinery, France Ferro Nickel to Market
Empresa Columbiana de Niquel Columbia (Hanna-Chevron Petroleum and Colombian Gov.t, 1980 +)	Oxide Ores Ferro Nickel	19,000	Market
P.T. Pacific Nickel, Indonesia (U.S. Steel — Amoco Minerals, U.S.A. — Hoogovens Ijmuiden N.V., Netherlands), 1983-1985	(Product — N.A.) Oxide Ore	51,000	Not Available
Amax, U.S.A.; B.R.G.M., France New Caledonia, 1985 +	Oxide Ore (Product — N.A.)	26,000-34,000	Not Available

Chapter 9 Nickel Resources and Reserves

WORLD NON-FERROUS METAL ORE RESERVES

Despite gloomy predictions from relatively uninformed sources, world ore reserves of key metal commodities such as *copper, lead,* and *zinc* ores have actually increased in the past decade. Figures calculated by the Deutsches Institut Fur Wirtschaftsforschung (German Economic Research Institute) were quoted recently by Walter Sies, General Manager of the giant metal and trading company, Metallgesellschaft A.G., to show that proven and probable reserves of bauxite had tripled over the last 10 years, *copper* and *zinc* ore reserves had more than *doubled,* and lead ore reserves had nearly doubled in the same period. Similarly the projected "lifetimes" of ore reserves, (even when such reserves are erroneously regarded as fixed quantities), *stretch* for decades and even centuries *longer into the future* than was believed ten years ago.

Considering only the "proven" and "probable" reserve categories, the metal tonnages contained in these world reserves have increased from 1966 to 1976 as follows:

1) *copper,* from 196,000,000 to 456,000,000 metric tons;

2) *lead,* from 93,000,000 to 175,000,000 tons;

3) *zinc,* from 75,000,000 to 185,000,000 tons.

9.1 World Nickel Resources and Reserves

(Excluding Sea-Bed Nickel Nodules)

Total ore reserves, as of 1976 could be as high as 75 million tons of contained nickel. This latest compilation indicates *an increase of more than five fold* in the past quarter century

1950	1964	1974	1976
14 million tons nickel contained	28 million tons nickel contained	33 million tons nickel contained	up to 75 million tons nickel contained (Sutulov)

Cuba and French New Caledonia probably have the world's largest known reserves. Cuba may have 16 to 18 million metric tons of nickel (according to Sutulov). New Caledonia may have some 15 million metric tons of nickel in ore of 1 per cent content or higher. These and other countries' reserves are tabulated below:

World Reserves — 1976

	Million Metric Tons
Cuba	18*
New Caledonia	14
Soviet Union	12*
Canada (mainly Ontario)	9
Indonesia	7
Africa (minimum)	2
Australia	5
U.S.A.	0.2
Others	7
Sub-total	74
Contingency	1
TOTAL	75

Sources: *Sutulov
U.S. Bureau of Mines.

N.B. Because of greatly increased labour and fuel costs, together with lower nickel prices in 1977, proven ore reserves of nickel in the Western World must have been seriously reduced in 1977, so that some of the above figures for certain countries must be considered to be on the high side.

It is important to note that about 40 per cent of the world's nickel reserves are located in Communist countries. Also, lateritic ores represent 80 per cent of the world's known nickel reserves. Both of these sources, of course, are in direct competition to Canadian material.

Table 9.1 depicts reserves of all categories of major world companies together with those of Comecon countries and these total about 70 million tons of contained nickel.

Adding together the reserves of Inco, Falconbridge, Societe le Nickel, Amax, Selection Trust, and Anglo-American affiliates, this sum represents at least 45 per cent of the world total ore reserves. If nickel producers, whose ore is processed on a custom basis via smelters of these companies are included as well as that of joint venture projects with Japanese companies, it can be determined that greater than 50 per cent of the world's reserves are controlled by organizations with a vested interest in preventing surplus production. While this is a formidable total, such surplus production could originate from Comecon countries alone. Therefore, it is to the advantage of leading nickel corporations to assist in the development of major nickel deposits in less developed countries before they are assisted by the major Eastern nations.

TABLE 9.1

NICKEL ORE RESERVES OF MAJOR COMPANIES AND COUNTRIES

Company	Reported Reserves (all categories) (million tons)	% Nickel	Nickel Content (million short tons)
Canada			
Inco Ltd. (1)	374	–	6.17
Falconbridge Nickel Mines Ltd. (2)	75.7	–	1.10
TOTAL Canada (3)			7.88
Dominican Republic			
Falconbridge Dominicana (2)	65.8	1.65	1.09
New Caledonia			
Societe le Nickel	N A	–	
Cofremmi (4) garnierite	12.	3.0	
laterite	15.5	1.	
garnierite	32.	3.2	
laterite	37.	1.34	15.
Inco Goro (French gov't.)	165	1.6	
Cofimpac (Samipac)	N A		
Amax	60	N A	
Others	N A		
Indonesia			
P.T. International Nickel (5)	250	1.76	
P.N. Aneka Tambang	N A		
Indeco	32	2.22	7.8
Pacific Nickel (Gag Island) (6)	190.	1.4	
Others	N A		
Australia			
Western Mining Corporation (7)			
Kambalda	24.334	3.2	
Windarra	9.135	1.49	
Scotia	.220	1.64	5.6
Selcast — Agnew (8)	47.	2.0	
Greenvale	40.	1.57	
Other	N A		
Cuba (9)			18-20
Yugoslavia			
Feni — 3 orebodies (10) Total	44.	0.6-1.4	0.44
Brazil			
Moro do Niquel	N A		0.5E
Codemin Niquel	15.	1.4	0.21
Baminco Niquel	40.	1.9	0.76
Cia Niquel Tocantins Niquel	20.	1.7	0.34
Greece			
Larymna (12)	91.	1.4	1.27
Euboea (13)	218.	1.1-1.3	2.62
Philippines	20.	2.2	0.44
India			
Sukhinda (4)	59.	.85	.50
Southern Rhodesia			
Rhodesian Nickel Corp. (11)			
Epoch	2.5	.75	.02
Shangani	23.	.7	.15
Union Corp.	60.	1.0	.60
Rio Tinto	N A	–	0.10E
Total Africa			2.3
U.S. (Principally Hanna Mining)			0.2
U.S.S.R. (9)			12.
Other			3
Total (short tons)			83.
Total (metric tons)			**75.**

Sources: (1) Inco Ltd. 1976 Annual Report
(2) Falconbridge 1976 Annual Report
(3) Department of Energy Mines & Resources Report MR157
(4) U.S. Minerals Yearbook, 1974
(5) Mining Magazine, May 1977, page 333
(6) World Mining, May 1977
(7) 1976 W.M.C. Annual Report
(8) Metal Bulletin, October 19, 1976
(9) Sutulov
(10) E.M.J. September, 1975
(11) U.S. Minerals Yearbook, 1975
(12) U.S. Minerals Yearbook, 1973
(13) Mining Magazine, March 1976, page 163

N/A Not Available

9.2 Canadian Nickel Resources and Reserves

Owing to the fact that the nickel industry has mine producers with larger market shares than is the case with copper and other non-ferrous metals, information is less freely available and hence neither INCO nor Falconbridge Nickel have published reserves on a mine by mine or provincial basis. Therefore, Canadian aggregate reserves are the best information available and this has been estimated as of January 1, 1976 by the Department of Energy, Mines and Resources of the Canadian Federal government to be 7.26 million metric tons of measured and indicated reserves of nickel metal contained in mineable ore. This source has published the only estimate of provincial breakdown known and this is given as:

Manitoba	1.56 million metric tons
Ontario	5.70 million metric tons
TOTAL Nickel in Reserves	7.26 million metric tons

9.3 Ontario Nickel Resources and Reserves

Ontario commenced the first of its studies to determine its inground inventories of various key commodities in 1975 as follows:

1) Uranium — completed (not published for reasons of confidentiality).

2) Zinc (published in aggregated form within a Canadian total figure).

3) Nickel — for completion early in 1978.

The Ontario reserves of approximately 5.7 million metric tons of contained nickel would appear at first sight to be ample, considering that Ontario annual nickel production has in recent years averaged about 0.2 million tons. It might be argued that, after allowing for mining, smelting and refining losses, Ontario has about 23 years' assured supply of nickel and that this assured supply may well be increased as a result of continued exploration around Sudbury and elsewhere.

Such an argument is dangerously over-simplified for two reasons. First, the life of an individual mine is governed by the relationship between production rate of the mining plant and the size of the orebody that can be mined using the plant. This relationship varies considerably so that some mines would have much less than average life and some more. Thus if additional reserves were not discovered, the Ontario nickel mining industry would tend to decline gradually over many years rather than end abruptly at some calculated date in the future. The start of that decline would be noticed in much less than 23 years.

Secondly, the argument fails to recognize that, by definition, ore reserves are material that can economically be mined at the time that the reserve calculation is made. Changing relationships between metal prices and costs of metal production will, of course, result in changes in "cut-off grade", i.e. in the lowest grade of material that can economically be mined. The geology of the area containing almost all Ontario nickel reserves, the Sudbury basin, is such that substantial quantities of mineral at close to the cut-off grade are likely to exist. Some of this material becomes ore if the relationship between metal prices and production costs improve. Increased metal prices and/or lowered costs may increase ore reserves as much as the discovery of a major new orebody. Conversely, low prices and high costs convert ore to waste. In the second case, the quoted ore reserves could be greatly reduced without one ton of ore being mined.

In order that provincial mineral policy may be based on a better understanding of factors such as those outlined above, a detailed inventory of provincial nickel reserves and resources is under way. However, the information obtained will not be available for publication due to the confidentiality of the data, which helps to protect the competitive position of the Ontario nickel industry.

The essential fact is that maintaining a constant or improved cost ratio will have more to do with sustaining the longevity of nickel mining in Ontario than any other fact.

ONTARIO MINERAL RESOURCE CLASSIFICATION

INCREASING LIKELIHOOD OF BECOMING ECONOMICALLY MINEABLE WITHIN 25 YEARS			INCREASING CERTAINTY OF EXISTENCE		
			DISCOVERED RESOURCES	PARTLY DISCOVERED	UNDISCOVERED
			Known Deposits	Expected Additional (In Known Areas)	Speculative (In Unknown Areas)
			Proven / Measured; Probable / Indicated	Possible / Inferred	
100%	Economic (now)		1A RESERVES	2A	3A
50%	Sub-economic	Para-marginal	1B CONDITIONAL RESOURCES	2B	3B
10%	Sub-economic	Sub-marginal	1C Conditional Resources	2C	3C

Chapter 10 Trade Barriers

Of the three major non-communist world nickel consuming areas (Europe, Japan, North America) only Japan subjects primary nickel forms to tariffs. Since 1951 Japan has controlled nickel imports by application of duties and allotments in order to protect and build a producing nickel industry operating smelters and refineries. At the present, ferronickels, nickel oxides, ingots, briquettes and rondelles are subject to 13% duty ad valorem. During the second half of the 1950's Japan's producer nickel prices reached as high as 200% above Inco's prevailing prices. The spread dropped to between 50-55% during the 1960's and has gradually closed to about 15-20% in 1977. Discounted nickel imports, after duty is applied, are about 10 to 20% lower than Japanese producer prices (July 1977).

Because of the dual nickel prices prevailing in Japan, the nickel smelters and refineries are under considerable pressure from Japanese steel mills to lower prices at least part way toward imported nickel price levels. Imports of nickel ores, concentrates and matte which enter duty free are based upon long term contracts pegged to world producer price nickel forms. The withdrawal of posted producer prices for nickel by Inco, Falconbridge et al, has led to Japanese producers requesting the negotiation of contracts with their suppliers (e.g.) Indonesia, Australia, etc.

A study of the nickel industry conducted by the Advisory Board to the Basic Industries Bureau in Japan has concluded in recommendations to the Ministry of International Trade and Industry that the nickel refinery and smelter industry be rationalized and modernized in order to become competitive with offshore nickel, and including eventual removal of duties.

In other nickel consuming areas tariffs are applied to primary nickel products by some countries but they have no real effect upon world nickel demand because of the dominant consumers in Japan, E.E.C. and North America. For the various tariffs applied based upon the Kennedy Round of GATT, see Table 10.1.

10.1 Non-Tariff Trade Barriers

Even though most major consuming countries do not apply duty to primary nickel products, import licences may be required, and sales tax in one form or another is applied based upon C.I.F. value ad valorem and tends toward protection of any nickel production in the country.

The communist bloc countries rely upon Russian supply and/or Cuban ore, concentrates and oxide and to a small extent Albanian ore. All communist countries imports are under control of each country's Foreign Trade Organization. As an example, Yugoslavia bases quota upon each individual request, especially ferronickel. Many of the smaller consumer countries require approval of their Central Bank or other appointed agency, and in some cases, deposit equal to the value of imports is held, at no interest, for periods of 1 year.

10.2 Overcoming Trade Barriers

The Tokyo Round of GATT negotiations has brought pressure upon Japan to bring non-tariff and tariffs applied to primary nickel products in line with E.E.C. and North America. It is believed Japan will succumb to the pressure and agree to gradual removal over a time period which will allow them to arrange new contracts with suppliers and also rationalize and upgrade producer plant in Japan. The subject of non-tariff barriers is under discussion in the Tokyo Round and could lead to easier access of primary nickel products to many countries but is not significant unless some of the new producer countries become major consumers of nickel, which is not likely to occur.

TABLE 10.2

TARIFFS

	Ferronickel	Nickel Oxides	Cathode Briquettes Ingots Rondelles	Nickel Anodes (For Plating)	Nickel Powder
E.E.C. (9 countries)	Free	Free	Free	Free	0.5%
U.S.A.	Free	Free	Free	5% ad val.	Free
Japan	13%	13%	13%	13%	Free
Canada	Free	Free	Free	Free	Free
Greece	Free	Free	Free	5%	0.5%
Austria	Free	Free	Free	8%	10%
Norway	Free	Free	Free	Free	Free
Spain	Free	Free	Free	4.5%	Free
Sweden	Free	Free	Free	Free	Free
Switzerland	0.50 Francs per 100 kg	0.25 Francs per 100 kg	0.25 Francs per 100 kg	16 Francs per 100 kg	0.40 Francs per 100 kg
Israel	Free	Free	Free	Free	Free
Iran	5%	5%	5%	10%	15%
Turkey	5%	5%	Free	15%	25%
South Africa	10%	10%	Free	Free	Free plus surcharge of 15% ad val.
Australia	Free	A$3.88/ton	A$3.88/ton	Free	Free
New Zealand	Free	Free	Free	Free	Free

Source: Department of Industry Trade and Commerce, Ottawa.

Chapter 11 Nickel in Scrap

The production of steel, ferrous and non-ferrous castings, nickel alloys, and other non-ferrous alloys containing nickel, in any nickel consuming country is dependent upon available forms of scrap. Scrap material is a vital ingredient, whether it is home scrap recirculated or purchased scrap, utilized in the make-up of the initial charge to the melting furnace.

Home or runaround scrap is produced in the primary metal producers plant during forming, shearing, forging and slitting operations. The production of stainless and alloy steels results in about a 40% loss in yield from the ingot although the losses have been reduced in mills utilizing continuous casting. High nickel alloys production can result in yields significantly lower, and as low as 20%. Generally, high alloy home scrap is re-melted and does not reach the outside scrap market. Prompt scrap is generated by the steel or alloy consumer producing fabrications, forgings, castings, and powder metal parts. At this stage, through reasonable control in the fabricators factory, the scrap is kept separate and either sold direct to steel mills, smelters, or to a scrap collector or dealer.

About one third of the scrap consumed is supplied to primary consumers (steel mills, smelters and foundries) through the scrap dealer or broker.

Obsolete or old scrap is generated through the process of discarding consumer goods, fabrications, transportation equipment, and other machinery and equipment.

In the case of high nickel and super alloys, unless the product is carefully identified the scrap is sold to special refiners in Japan and Europe primarily.

In the United States the pattern of production and consumption of scrap is well documented and to a reasonable degree indicates the scrap consumption patterns that occur in Europe, Japan and other nickel consuming countries.

As an example, ferrous scrap recovery in the U.S.A. has increased markedly in the past 15 years from 28% in 1960 to 35% in 1974.*

Generally, the U.S.A. is a net exporter of ferrous scrap whereas Canada, Germany, Italy and Japan are net importers, although Canada is considered as a net exporter of stainless steel scrap.

During periods of high production it is usual for the U.S.A. to restrict scrap exports as do other countries and Canada also places embargoes upon export during shortages.

The foregoing indicates the volatility of scrap availability and, of course, price. Indeed, scrap can be considered a resource similar to metal ore in that as prices rise the reserves in any country increase because it becomes profitable to collect and segregate obsolete scrap not normally marketable.

* Metal Statistics 1976, Fairchild Publications Inc.

11.1 Scrap Industry and Prices

The prime sources of nickel in prompt and obsolete scrap are in nickel stainless steels, non-ferrous alloys, high nickel alloys and super alloys. Cupro-nickels, monels, pure nickel, inconels, nickel catalysts, and 200 and 300 series stainless are all sources of nickel units as well as nickel chemicals, magnets and catalysts.

The following table shows the recovery of nickel in non-ferrous scrap in the U.S.A. from 1946,* (includes new and old scrap) in metric tons of nickel.

* U.S.B.M. Statistics.

TABLE II.1.1

U.S. RECOVERY OF NICKEL IN NON FERROUS SCRAP (metric tons)

1946	7,483	**1954**	7,806	**1962**	10,077	**1970**	21,010
1947	8,656	**1955**	10,469	**1963**	17,233	**1971**	24,346
1948	8,029	**1956**	13,481	**1964**	20,969	**1972**	32,592
1949	5,153	**1957**	10,902	**1965**	17,606	**1973**	29,601
1950	7,979	**1958**	6,723	**1966**	24,292	**1974**	18,988
1951	7,804	**1959**	8,662	**1967**	18,807	**1975**	16,221
1952	6,785	**1960**	8,556	**1968**	12,756		
1953	7,577	**1961**	9,696	**1969**	17,033		

Recovery has increased fourfold since the beginning of the 1950's.

The nickel is utilized in nickel base, copper base, aluminum base, ferrous and high temperature alloys and chemicals.

The importance of scrap as a major ingredient in primary metals can be seen when comparing total industrial demand for nickel vs total primary nickel demand in the U.S.A. from 1964 to 1976*.

TABLE 11.1.2

U.S. PRIMARY NICKEL vs SCRAP NICKEL CONSUMPTION

	Total Nickel	Nickel in Scrap	% Scrap Nickel
	'000 metric tons		
1964	119.8	46.2	38.6
1965	172.7	46.2	27.0
1966	264.8	57.2	21.6
1967	213.3	47.4	22.2
1968	180.4	33.2	18.4
1969	202.7	64.4	31.8
1970	202.7	44.2	21.8
1971	180.2	57.2	31.7
1972	213.5	61.2	28.7
1973	248.1	59.8	24.1
1974	257.3	58.5	22.7
1975	177.9	37.7	21.2
1976	193.4	42.6	22.0

Source: U.S.B.M.

The effect of the U.S. Government embargo upon scrap exports can be seen in 1968 and 1969. At the time a shortage of nickel resulted in scrap exports increasing markedly. The embargo diverted the nickel units into U.S. primary metal producers plants. Nickel cathode was $1.03 per pound until November, 1969 when it increased to $1.28 per pound. Nickel in scrap ranged from $5.80 to $6.40 per pound, which dropped to between $2.00 to $4.00 per pound in December. Merchant nickel commanded prices of $7.15 per pound in the same period.

In the stainless steel industry operating electric furnaces about 95% of a melt is generally scrap steel made up of #1 Heavy melt scrap or equivalent high grade carbon steel plus stainless runaround scrap plus purchased scrap, plus the chromium, nickel, molybdenum, etc. additions required to produce the specified stainless steel grade. The relationship of stainless steel scrap consumed, purchase of stainless scrap and total ingot tonnes produced 1961-1974* in the U.S.A. is shown below.

TABLE 11.1.3

U.S. STAINLESS STEEL STATISTICS

('000) Metric Tons

	Ingot Production	Total Stainless Scrap	Purchased Scrap		Ingot Production	Stainless Scrap	Purchased Scrap
1961	1,031	601	189	**1968**	1,297	796	341
1962	983	602	208	**1969**	1,422	1,078	553
1963	1,091	652	227	**1970**	1,158	862	436
1964	1,307	761	282	**1971**	1,141	876	460
1965	1,353	762	274	**1972**	1,413	844	375
1966	1,496	942	372	**1973**	1,716	974	416
1967	1,315	783	324	**1974**	1,955	1,167	501

Purchased scrap has ranged from a low 31% in total stainless scrap used in 1961 to a high of 52.5% in the early 1970's. Total stainless scrap utilized each year is about 60% of ingot production although 1969 reached a high of 75% during the embargo placed upon exports. Purchased stainless scrap was a low of 18% in 1961, and reached a high of 40% of ingot production in 1971.

At the present time bundles of stainless 18/8 scrap is priced about $490/long ton. Charge chrome is about $0.35 per pound. The intrinsic value of a long ton of 18/8, allowing for 8.5% nickel, is therefore about $578.00. In essence, because scrap, chromium and nickel are in free supply the values in stainless 18/8 are discounted about 17%. The discount never drops below 10% in times of free supply but has climbed much higher than intrinsic value during nickel shortages.

Total nickel units utilized in scrap since 1964 in the U.S.A. has varied from a low of 33.2 thousand metric tons/year during heavy exports to 64.4 thousand metric tons/year. U.S.B.M. estimates 1977 will be about 50,000 and by 1985 90,000 metric tons in the U.S.A. and 250,000 in the rest of the world. The turnaround from a price decline of 18/8 stainless scrap to an escalation of the prices the steel mills and foundries are willing to pay is considered one indication of rising nickel demand.

* U.S.B.M., Inco.

11.2 #1 Heavy Melting Scrap

High quality carbon steel scrap is an important ingredient in stainless steel production and consumption ranges from 35 to 50% of a melt. The stainless producers must compete with the large integrated steel mills for #1 heavy melt or equivalent.

Total consumption of iron and steel scrap including home scrap and receipts by mills and foundries are shown below.

TABLE 11.2.1

U.S. CONSUMPTION SCRAP ('000 short tons)

	Consumption	Receipts		Consumption	Receipts
1952	69,023	34,693	**1964**	84,626	31,831
1953	77,131	33,556	**1965**	90,359	35,804
1954	61,354	25,855	**1966**	91,583	36,671
1955	81,375	35,735	**1967**	85,361	32,654
1956	80,315	36,846	**1968**	87,060	33,587
1957	73,549	31,086	**1969**	94,816	36,929
1958	56,360	23,291	**1970**	85,559	34,148
1959	66,062	29,043	**1971**	82,567	34,208
1960	66,469	26,095	**1972**	93,371	41,670
1961	64,427	25,305	**1973**	103,589	44,711
1962	66,160	25,284	**1974**	105,484	51,335
1963	74,621	29,432	**1975**	82,768 (est)	37,300 (est)

TABLE 11.2.2

#1 HEAVY MELTING SCRAP PRICES

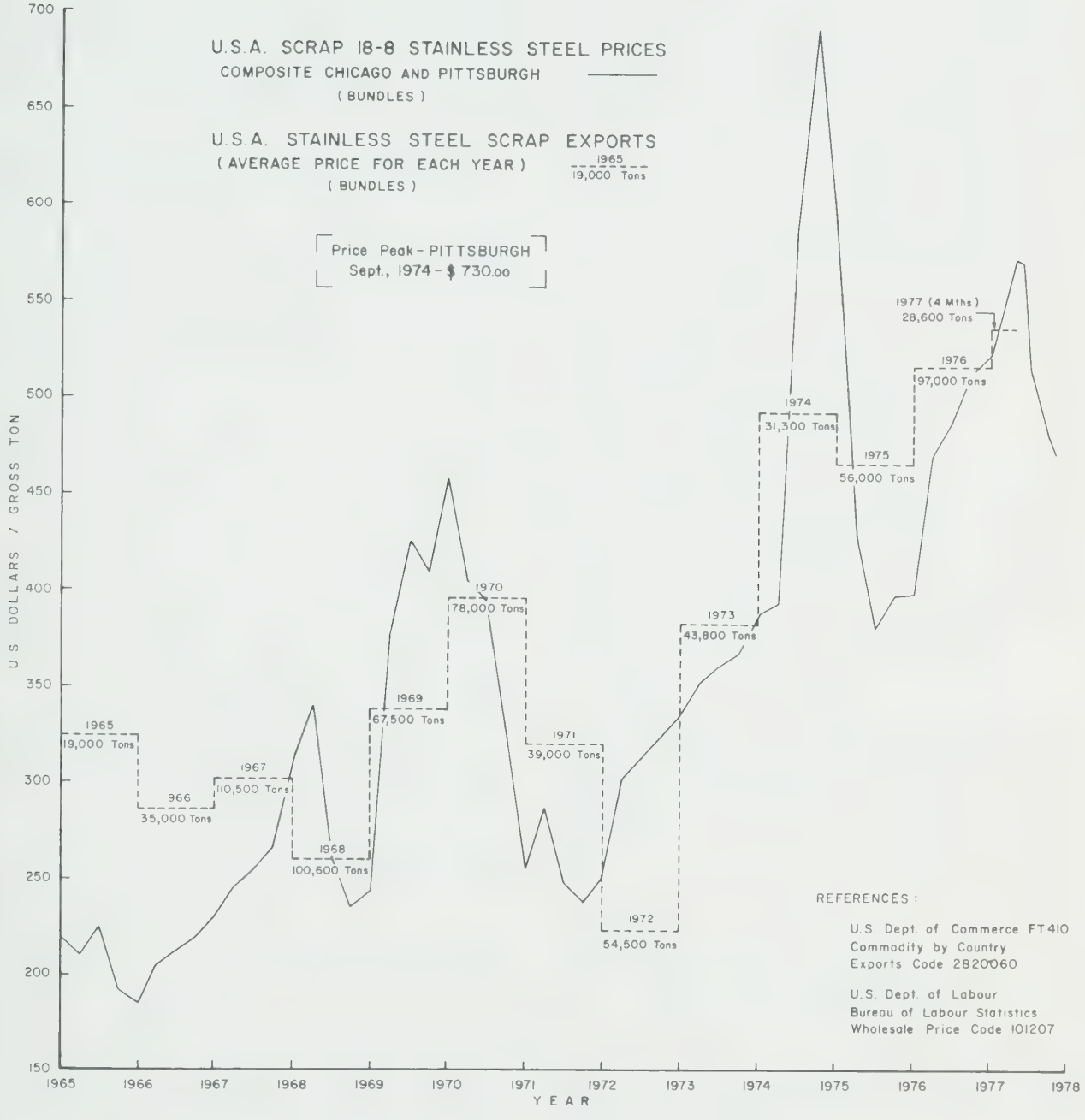
The composite average price of #1 Heavy Melting scrap (American Metal Market) in dollars/long ton is shown below:

1952	$41.89	1960	$33.20	1968	$25.94	1976	$78.02
1953	39.90	1961	36.37	1969	30.56	1977 January	69.00
1954	28.74	1962	28.34	1970	44.95		
1955	39.75	1963	26.89	1971	34.46		
1956	53.45	1964	36.50	1972	36.63	1977 October	51.50
1957	47.10	1965	34.27	1973	57.67		
1958	37.81	1966	30.66	1974	107.83		
1959	37.69	1967	27.63	1975	72.52	1977 December	64.79

The prices reached a low of $23.76 in March, 1954 and an all time high of $126.30 in July, 1974. It is interesting that during the severe nickel shortage of the late 1960's #1 Heavy Melting Scrap was not high priced. The price did reach new peaks during periods when all countries were expanding production and world demand for steel caused shortages (1956-1957 and 1973-1974).

* Metal Statistics.

STAINLESS STEEL SCRAP PRICES



Chapter 12 Impact of Technology

12.1 Effect of Fuel Price Increases on Costs

The fourfold price increase, which occurred in 1973, for fuel oil was a major contributor to rapid inflation of costs in all industrial process, not to mention consumers' costs for transportation, heating and electricity. The effect upon nickel mining and processing has been dramatic, particularly in the case of the oxide ores whether they are processed to ferro nickel, nickel oxides, or pure nickel briquettes and powder.

Much of the cost of mining oxide ore is fuel oil required for drying the ore, production of electric power, and reduction of nickel and cobalt in the ore either in kilns or other proprietary equipment. Naphtha gas is also used in reduction.

Recent statements by Marinduque Mining and Industrial Corporation, Philippines, (1976 Annual Report) and Inco Limited (Preliminary Prospectus, November 4, 1977) in reference to Exmibal, Guatemala Project indicate fuel costs to be over 50% of operating costs. Marinduque indicates about 53% of operating costs are fuel, although it is operating at only 45% capacity.

A comprehensive paper "The Energy Picture in Nickel Production," (J. Dasher, Mining Metals Division, Bechtel Corporation, San Francisco, U.S.A.) examined the energy inputs for various nickel processes to depict the extent of the impact of higher energy costs on nickel production.

Data was not available for all oxide and sulphide operations in the world, or all the processes, such as the Inco carbonyl process. Nevertheless, converting all energy inputs to kilowatt-hours per pound of nickel produced, and allowing credits where waste heat, and gases are utilized, Mr. Dasher has identified the energy consumption for most operations employed in the production of a final nickel product. Mining and milling, smelting, converting, matte separation, hydrometallurgical leaching, electrorefining were given values for sulphide ores. Oxide ore energy requirements for ferro nickel production, smelting to matte, reduction roasting, leaching processes, reduction to metal and electrorefining are identified.

Sulphide ores refined to metal by electrorefining or leaching reduction to powder including all intermediate energy requirements mentioned above, requires about 10 kWh per pound of nickel produced.

Oxide ores processed to ferro nickel (25% nickel) requires 16-19 kWh/pound of nickel and oxide ores processed to nickel oxides or nickel powder may require 20 kWh up to 38 kWh per pound of nickel produced.

The resultant effect on production costs assuming an increase from an average base cost early 1973 of $0.006 per kWh to $0.026 per kWh at the end of 1976 has increased costs an average of $0.20 pound of nickel for sulphide ores and $0.40 to as high as $0.76 pound of nickel for oxide ores.

There are, of course, variables which affect a particular plant operation that can be an advantage at the present time, such as Inco and Falconbridge Sudbury operations which depend heavily upon purchased electric power. Also, P.T. International Nickel Indonesia will employ hydroelectric power resulting in lower total operating costs as compared to operations dependent upon power generated by thermal plant which includes all the projects presently being completed except Inco, Indonesia.

When the increased energy costs per pound of nickel are compared to the price change from December 1972 $1.53 per pound to the present price November, 1977, of $2.08 per pound the impact is dramatic. In the case of sulphide ores, the energy costs alone account for 36% of the total price increase in 4 years and for oxide ores 73% to 138% of the price increase. If labour cost increases and the cost of interest for debt servicing, especially for new projects is added, it is evident why many nickel projects are now operating at a loss.

In essence, the price of nickel has increased 36% and energy costs 400% and in the case of oxide ore processing energy costs have increased a minimum of $0.40 to as high as $0.76 per pound while the price increase of nickel is up $0.55/pound.

12.2 Potential Major Demand Shifts

The use of oxygen in open hearth and electric arc steel furnaces triggered a major change in steel making and in turn stainless steel production almost 30 years ago. The advent of the tonnage oxygen blow in electric arc stainless refining presented melting superintendents with the opportunity to employ lower cost primary nickel units as a larger percentage of the total primary nickel charged. Growth in consumption of impure Class II nickel commenced, especially Ferronickel because it was no longer a major problem to remove carbon from the melt.

In 1955 nickel as Ferronickel was about 7% of total western world consumption and 16.1% in 1960. Class I nickel product consumption dropped in the same period from 81.0% to 72%. Nickel oxide consumption ranged from 11 to 12% in the same period. The period 1960-1965 showed little change in preference with respect to consumption but this is partly related to availability of the various products, as well as the process limitations of using more Class II nickel during the early 1960's.

12.3 Argon Oxygen Decarburization

The Union Carbide Corporation development of the AOD vessel or converter in 1968, in conjunction with Joslyn Steel Company, Indiana, U.S.A. has had profound effects upon the stainless industry. The process makes use of inert gas (Argon) with Oxygen which facilitates decarburization of a melt and in much less time. It has resulted in the separation of melting and refining and in essence doubles the capacity of a melting facility. Generally the steel is melted and chromium and nickel are brought up to specification with little refining done in the electric furnace except sulphur removal.

Since the first installation in 1968 the AOD installations have grown rapidly to about 70 at the present time. Unit size ranges from 4-5 tons up to 100 tons and will no doubt be built larger.

The use of AOD's has had a further major effect upon the various nickel products that prove useful and economical, in particular in stainless steel production.

Lower cost chromium units are employed and much larger percentages of lower grade nickel units. Ferronickel, nickel oxide and other impure forms of nickel make up most of the primary nickel units consumed. In essence, 90% of the nickel units in the melt are made up of about 60% scrap, 30-35% ferronickel and nickel oxide. The final 10% may not necessarily be cathode nickel, briquettes or rondelles depending upon the steel specification and nickel price. Slightly impure nickel containing small amounts of oxygen and copper grades are proving suitable as final charge metal.

Since the adoption of AOD's the use of ferronickel has grown to 27% of total western world consumption in 1970 and continues to grow. Class II nickel total consumption is now about 47% of total nickel consumption. The trend is expected to level at about 50% and has caused major nickel producers to commence development of less expensive nickel metal products and the deliberate reduction of the production of cathode nickel. Several new nickel products developed for use in steel and ferrous casting production have been announced in 1977.

12.4 Other Developments

The use of vacuum has also been growing in several sectors of metal melting production. Vacuum degassing developed in Witten, West Germany removes carbon and silicon by the introduction of oxygen in a separate vessel. Republic Steel Corporation developed the V.O.D. which incorporates separate introduction of argon and oxygen in the vessel while the steel is under vacuum.

Electroslag refining is also applied to stainless production, particularly for flat rolled stainless because of the low incidence of metallic inclusions.

Mechanised and now totally enclosed bulk handling of alloys, including pneumatic systems is changing the needs of the stainless producers operating AOD's and V.O.D.'s. Free flowing materials handled by conveyor systems will grow in importance as evidenced in Allegheny Ludlum Steel Corporation's new installation in Brackenridge, Pennsylvania.

The gradual growth of continuous casting unit installations will affect the stainless steel and carbon steel scrap market because yields are increased thereby reducing homescrap generated in the steelmill.

Ultra low carbon chromium stainless steel has been studied and research continues. Airco-Temescal, U.S.A. has produced and studied vacuum induction melted (0.002% carbon) stainless and indications are corrosion properties and mechanical properties are equal to austenite stainless steel. The economics of production will probably limit the development. Ultra high powered electric arc furnace melting is growing rapidly, and shortens melting time markedly.

Ductile Steel Company, U.K. has produced a double sandwich of outer layers of carbon steel (galvanized) and inner layers of stainless steel. After galvanizing the steel is parted to produce 2 coils of 10% thick stainless on one side and galvanized steel on the reverse side. Development of such a product could lead to many applications where solid stainless steel was not economic in the past.

References: Metal Bulletin
A.M.M.
Canavest House Limited.

Chapter 13 Substitution

13.1 Stainless Steel

Chromium is the principal alloying element in stainless steel and is almost always present in amounts in excess of nickel. Nickel has a significant effect on corrosion resistance in the presence of chromium. However, the principal function of nickel is to promote the formation of austenite at high temperatures, the retention of austenite at and below room temperatures and to retard the change from austenite to martensite when the metal is being cold worked. Thus, chromium-nickel stainless steels offer corrosion resistance, and desirable mechanical properties well above and below room temperature.

There are three basic families of stainless steel alloys in use:

1. The Ferritic and Martensitic Stainless Steels containing chromium generally from 11 to 27%, and depending upon the grade small amounts of nickel, manganese, copper and silicon. This is the basic 400 Series grades of stainless steel.
2. The 300 Series Austenitic Stainless Steels contain from about 6 to 37% nickel and in the higher nickel grades the nickel present is a higher percentage than chromium.
3. The 200 Series stainless steel development occurred during the concern for nickel availability in World War II. Manganese and nitrogen are used to replace about ½ the nickel. Nitrogen enhances austenite formation at high temperatures and manganese at room temperature. The 200 Series contains 5 to 10% manganese, 3.5 to 6% nickel and 0.25% nitrogen maximum.

The many grades of stainless steels compete for market share of the total stainless steel consumption in the world based upon price, alloy availability and properties of the steel in relation to the application.

From the beginning of the 1960's the demand for nickel stainless steels (200 and 300 series) grew faster than total demand and levelled at about 68% in 1968. Over the past 10 years, the production share of 300 series reached a low of 64% (1969) and a high of 71% in 1973 in the U.S.A. Other stainless grades exhibit no growth in production share as a percentage of total stainless production.

The ferritic and martensitic grades in the U.S.A. (production) is about 30%.

There does not appear to be any reason to expect an increase or decrease in share of production of 300 Series.

13.2 Molybdenum and Other Alloy Additions vs. Nickel

Aluminum, Molybdenum, Columbium, Cobalt, Silicon, Titanium, Tungsten, Tantalum and Vanadium have all found uses either to enhance resistance to oxidation at high temperatures, add high temperature strength, improve creep resistance, or as a stabilizer in stainless steels and ferrous super alloys.

In most of the stainless steel and ferrous super alloys other alloy additions enhance the properties and do not result in lower nickel additions. In fact, the higher nickel containing grades 12-35% nickel are the alloys used at higher temperatures and in severe corrosive media and their performance is aided by the other additions whether they are wrought or cast. The chromium-nickel-cobalt-iron alloys containing 12% to 30% cobalt compete with some high nickel alloys and have the effect of lowering nickel consumption.

13.3 Constructional, High Strength Low Alloy, and Ultra High Strength Steels

Nickel in carbon steels strengthens and refines ferrite and pearlite thereby lowering the carbon content required to obtain a desired strength and hardness. Nickel also allows heavier sections to be hardened by heat treatment without cracking or distortion.

The effect of nickel and other alloys such as chromium and molybdenum were found to be complementary thus allowing a lowering of nickel content from 3 to 5% down to 0.40% to 3.25%.

The development of the AISI 21xx to 86xx alloy steel grades occurred over 50 years and resulted in a drop from 6% nickel average to about 1.1% or lower in automotive uses, particularly when molybdenum was added to the steels with chromium.

H.S.L.A. steels developed for structural steels applications in an effort to save weight and gain resistance to atmospheric corrosion.

The original steels all aimed at developing 50,000 psi yield strength, contained nickel and silicon and manganese. Later developments resulted in chromium, molybdenum and copper additions although most of the steels contain nickel from 0.50% to 1.0% nickel.

Improved heat treatment equipment, and techniques, and forging techniques has resulted in lowering the alloy content including nickel in the steels while retaining the desired properties. No change in this trend is predicted.

The ultra high strength steels developed at the beginning 200,000 psi yield and later 250,000 psi yield strength. The original steels were the result of careful heat treatment of conventional 1.85% nickel AISI 4340. The introduction of silicon and the lowering of carbon enhanced the properties. Some of the newer steels developed contain no nickel while some contain up to 3.60%, with varying amounts of Vanadium, Molybdenum and Silicon.

In summary, the research and development of alloy steels continues and the growth in consumption of alloy steels continues. However, because of the short supply of nickel several times in the past 40 years nickel usage per ton of alloy steel has declined and is not expected to increase because of advances in technology of alloy development and heat treatment.

13.4 Nickel Plating

The development of nickel plating occurred in the late 19th century and improvements of electroplating baths and nickel anode products has been continuous since then.

Nickel is used for improved corrosion resistance and surface improvement primarily but is also used for electroforming of record mothers and masters, printing plates and other uses.

During nickel shortages and when nickel price increases were large in the opinion of consumers, other materials such as copper, brass, chromium, lead, tin in combination have replaced nickel although not altogether satisfactorily. Investigations are continuing, particularly the direct application of chromium on aluminium and steels. However, new uses of nickel plating such as black deposits of nickel upon other metals for use in solar energy applications, because of high thermal emissivity properties hold considerable promise.

There does not appear to be any definite trend of a lower nickel consumption in electroplating as compared to total consumption of nickel.

13.5 Other Products

Depending upon the corrosion, high or low temperature requirements, or other properties, needed in a part or fabrication, many substitutes for nickel or nickel containing material can be applied. Aluminium alloys compete with stainless steel in automotive, transportation and architectural uses. Steel clad with stainless steel, titantium, monel or cupro nickels can reduce nickel consumption in many applications. Molybdenum and cobalt based superalloys and ceramic materials can replace high nickel or nickel containing ferrous based superalloys.

Plastics on steel compete in many applications, e.g., plastic versus nickel-chromium electroplated parts. Platinum, palladium, cobalt and other materials compete with nickel in catalyst applications.

Iron based and iron manganese and precious metal electrodes for spark plugs compete with high nickel alloy materials. There is competition for pure nickel coinage, either sandwiches of nickel on copper or lower nickel alloy materials, and many materials compete with nickel uses in batteries.

Depending upon availability and price, substitution of nickel will take place but only where the substitution is shown to be technically satisfactory and is proven in applications over many years. The major uses for nickel are in materials and applications that are mature in the development stage and it is difficult to rapidly apply new materials in place of nickel containing materials.

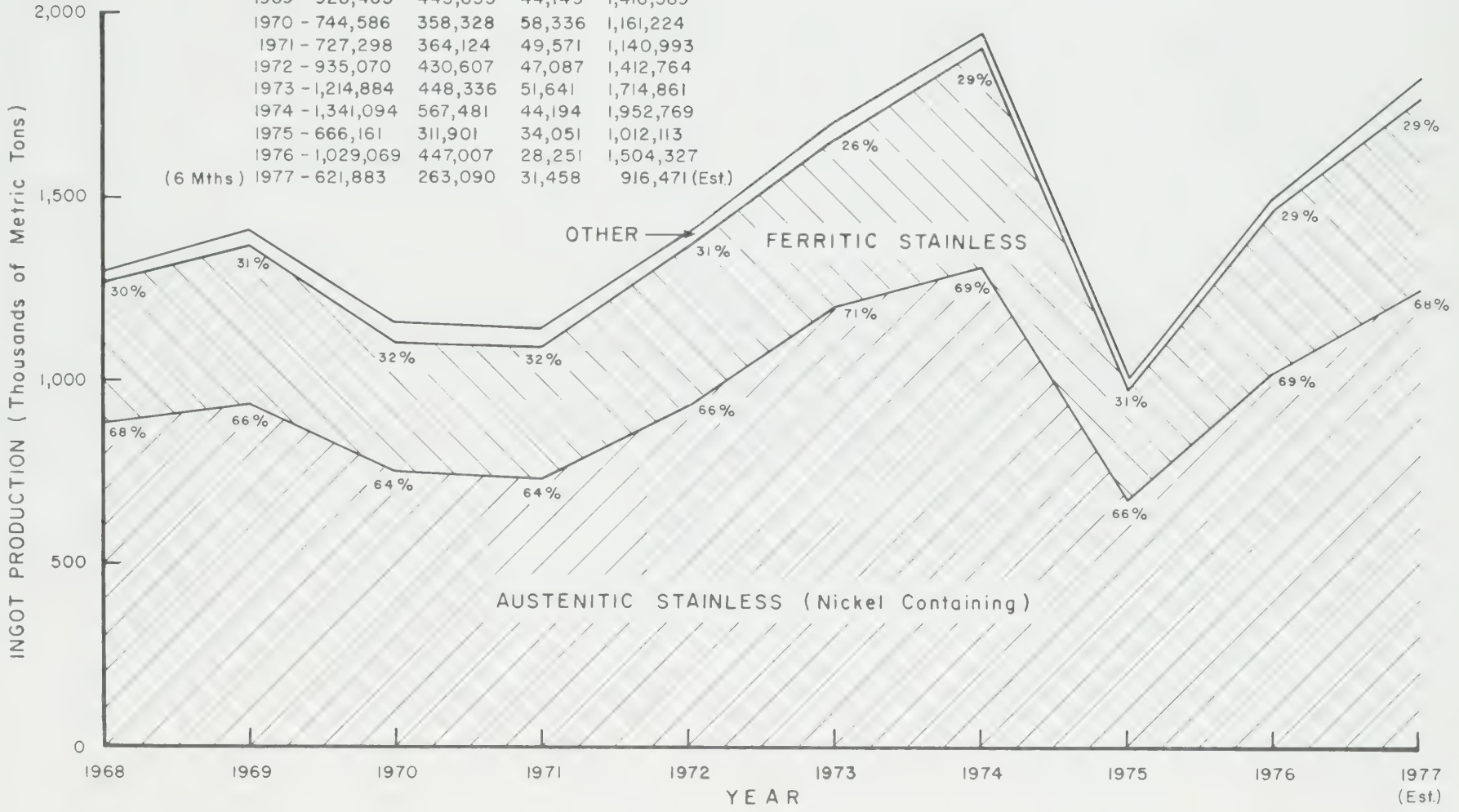
Certainly at the present there is no drive to replace nickel because of the ample supply.

U.S. STAINLESS STEEL PRODUCTION 1968-1977

(Thousands of Metric Tons)

	AUST.	FERRITIC	OTHER	TOTAL
1968 -	880,372	394,938	21,928	1,297,238
1969 -	928,405	443,835	44,149	1,416,389
1970 -	744,586	358,328	58,336	1,161,224
1971 -	727,298	364,124	49,571	1,140,993
1972 -	935,070	430,607	47,087	1,412,764
1973 -	1,214,884	448,336	51,641	1,714,861
1974 -	1,341,094	567,481	44,194	1,952,769
1975 -	666,161	311,901	34,051	1,012,113
1976 -	1,029,069	447,007	28,251	1,504,327
(6 Mths) 1977 -	621,883	263,090	31,458	916,471 (Est.)

SOURCE – A.I.S.I. (U.S.A.)



APPENDIX A1

SELECTED USSR STATISTICS

TABLE A1.1

SOVIET UNION — BASE METAL PRODUCTION

(in metric tons)

Year	Nickel	Year	Nickel	Copper
1932	Nil	1960	58,000	500,000
1937	2,000	1961	75,000	550,000
1942	11,000	1962	80,000	630,000
1950	33,000	1963	80,000	700,000
1955	45,000	1964	80,000	720,000
		1965	85,000	750,000
		1966	90,000	800,000
		1967	95,000	900,000
		1968	100,000	960,000
		1969	105,000	1,100,000
		1970	110,000	1,100,000
		1971	126,000*	1,150,000*
		1972 (smelter)	125,000	1,225,000*
		1973 (smelter)	135,000	1,300,000*
		1974 (smelter-U.S. B.o.M.)	145,000	1,350,000*
		1975 (Plan)	150,000	1,420,000*
			(152,000 — "M.A.R.")	
		1976 est.	160,000	N. A.
		1977 (forecast)	168,000	N. A.
		1980 (forecast)	190,000	N. A.

N.A. — not available.

Source: A. Sutulov 1932-1970
U.S. Bureau of Mines 1972-1974
Mining Annual Review 1975-1980
Metallgesellschaft

TABLE A1.2

U.S.S.R. EXPORTS OF PRIMARY NICKEL TO MAJOR WESTERN COUNTRIES

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
	metric tons									
to Canada	–	—	—	—	—	—	1,364	—	—	—
to United States	200	400	1,006	783	20	100	3,264	10,029	N.A.	N.A.
to Japan*	N.A.	6,000	5,000	4,613	4,054	4,423	4,548	4,757	2,168	2,950
to Italy	900	1,900	400	500	500	N.A.	N.A.	N.A.	N.A.	N.A.
to West Germany	N.A.	N.A.	5,586	5,478	4,167	3,341	4,991	6,395	3,032	N.A.
to U.K.	7,400	8,100	6,500	1,100	10,500	200	N.A.	N.A.	N.A.	N.A.
to Sweden	N.A.	N.A.	270	3,195	1,858	690	1,546	N.A.	N.A.	N.A.
to France	N.A.	N.A.	N.A.	1,900	N.A.	1,200	2,100	N.A.	N.A.	N.A.
to Others	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TOTAL estimated	N.A.	16,500	19,000	22,500	22,500	10,500	18,500	21,500	N.A.	20,000 est.
TOTAL U.S.S.R. NICKEL OUTPUT	95,000	100,000	105,000	110,000	110,000	125,000	135,000	145,000	152,000	160,000
APPROXIMATE APPARENT INTERNAL SOVIET CONSUMPTION (INCLUDING STOCKPILING *AND SHIPMENTS TO COMECON*)	N.A.	83,500	86,000	87,500	87,500	114,500	116,500	123,500	125,000 est.	130,000 est
Estimate by Metallgesellschaft	N.A.	N.A.	N.A.	N.A.	N.A.	100,000	100,000	105,000	115,000	N.A.

N.A. — not available.

Source: World Metal Statistics; Department of Energy, Mines and Resources, Canada; U.S.B.M.
* Refined — source: Sumitomo.

APPENDIX A2

ADDITIONAL CANADIAN STATISTICS

(Shipments & Exports)

TABLE A.2.1

SELECTED STATISTICS

I. *INCO SHIPMENTS TO U.K.* (NICKEL CONTAINED IN MATTE & OXIDE OF ONTARIO AND MANITOBA ORIGIN STATISTICS CANADA) (TO INCO'S CLYDACH (*WALES*) *REFINED*) MOSTLY CONVERTED TO NICKEL PRODUCTS IN U.K

	1971	1972	1973	1974	1975	1976
(Metric tons)	50,349	49,442	34,019	34,019	45,359	37,195

II. *INCO SHIPMENTS TO U.K.* (*PLATINUM GROUP METALS* IN CONCENTRATES — ALMOST ENTIRELY OF ONTARIO ORIGIN (TO INCO'S ACTON, LONDON *REFINERY*)

(Metric tons)	14	12	13	15	13	12

III. *INCO SHIPMENTS TO U.S.A.* (*IRON OXIDE PELLETS*)

ABOUT 700,000 short tons a year

IV. *PERCENTAGE OF TOTAL INCO ONTARIO MINE OUTPUT OF NICKEL WHICH IS SENT TO U.K.*, estimated

33 percent	37 percent	22 percent	20 percent	30 percent	24 percent

Source: Statistics Canada
Estimates: Mineral Resources Branch, Ontario

TABLE A.2.2

NICKEL EXPORTS FROM CANADA TO CHINA

	1972		1973		1974		1975		1976	
	metric tons	$'000	metric tons	$'000	metric tons	$'000	metric tons	$'000	metric tons	$'000
Nickel in Oxide	-	—	1.2	3	—				N.A.	
Nickel anodes, Cathodes, ingots, rods	4,630.0	13,112	17,979.4	58,855	20,004.1	65,446	500.0	2,160	N.A.	

Source: Statistics Canada.

APPENDIX A3

CANADIAN FINANCIAL STATISTICS

TABLE A3.1

INCO LTD. FINANCIAL STATISTICS

	1946	1950	1956	1958	1962	1967	1970	1971	1974	1976
	$ million									
Net Sales	133.1	228.0	444.7	322.0	450.7	713.2	1055.8	789.2	1684.6	2040.3
Operating Costs	84.8	141.1	264.3	239.1	288.5	469.6	673.2	526.3	989.9	1496.6
Provision for Taxes	10.2	27.6	61.0	28.2	37.4	78.3	121.1	35.4	248.4	150.4
Net Profit	29.7	48.8	96.3	39.7	94.2	141.8	208.6	94.2	306.0	196.8
Nickel Deliveries — million lbs	201.1	256.4	286.1	205.8	318.2	463.5	518.9	342.5	549.1	409.8
Copper Deliveries — million lbs	149.8	212.9	271.3	210.6	267.3	310.9	348.1	340.3	367.2	256.0
Nickel and Copper Del. — million lbs	350.9	469.3	557.4	416.4	585.4	774.4	867.0	682.8	916.3	765.8
Net Profit, Nickel and Copper — $/lb	0.08	0.10	0.17	0.10	0.16	0.18	0.24	0.14	0.33	0.26
Return on Total Assets* — %	9.8	14.3	16.8	7.2	12.4	12.8	11.3	4.3	10.7	5.4
Employees – Metals Business — No.	18,108	22,503	27,902	24,999	27,606	32,552	37,313	36,089	32,458	38,696

* Defined as (net profit ÷ current and fixed assets) × 100%

Source: Inco Ltd. Annual Reports.

TABLE A3.2

FALCONBRIDGE NICKEL MINES FINANCIAL STATISTICS

	1946	1950	1956	1958	1962	1967	1970	1971	1974	1976
	$ million									
Net Sales	5.106	17.380	49.9	56.756	73.760	94.442	160.674	154.236	457.82	483.80
Operating Costs	4.053	11.302	30.6	32.040	40.341	64.178	95.643	105.652	309.084	426.151
Provision for Taxes	0.189	1.568	0.302	1.400	6.420	6.786	5.740	4.946	33.954	7.439
Net Profit	0.516	2.707	7.164	7.053	20.321	24.931	43.930	17.633	21.976	14.703
Nickel Deliveries — million pounds	N.A.	N.A.	43.4	48.5	61.1	74.8	84.1	85.9	89.5	143.4
Copper Deliveries — million pounds	N.A.	N.A.	26.4	30.9	33.8	32.4	56.9	61.0	54.0	139.3
Total Nickel and Copper Deliveries — million pounds	N.A.	N.A.	69.8	79.4	94.9	107.2	141.0	146.9	143.5	282.7
Net Profit Nickel and Copper Deliveries — $/lb.	N.A.	N.A.	0.10	0.09	0.21	0.23	0.31	0.12	0.15	0.05
Return on Total Assets — %	3.5	14.4	10.0	9.4	N.A.	10.0	11.9	3.9	2.8	2.0

Source: Falconbridge Nickel Mines Ltd. Annual Reports
Ventures Ltd. Annual Reports.

TABLE A3.3

SHERRITT GORDON MINES LTD. FINANCIAL STATISTICS

	1954	1956	1958	1962	1967	1970	1971	1974	1976
					$ million				
Net Sales	4.521	19.802	20.645	23.647	49.375	90.889	73.958	192.958	179.428
Operating Costs	2.757	10.235	13.728	16.799	38.893	55.760	60.798	141.934	166.070
Provision for Taxes		0.125		0.080	2.410	13.0	(1.995)	17.535	3.165
Net Profit	0.468	5.610	3.234	2.048	2.992	15.843	7.497	23.046	4.131
Refined Nickel Sales — million pounds	N.A. start up year	19.240*	22.213*	18.767	23.553	21.643	14.587	16.142	22.454
Refined Copper Sales — million pounds	N.A. start up year	9.006*	9.891*	11.177	10.556	31.614	60.432	101.692	76.190
Total Nickel and Copper Sales	N.A.	28.2	32.1	29.9	34.1	53.3	75.0	117.8	98.6
Net Profit ÷ Nickel + Copper Sales ($ lb)	N.A.	0.20	0.10	0.07	0.09	0.30	0.10	0.20	0.04
Return on Total Assets %	0.8	9.1	4.7	2.8	3.5	13.3	6.0	12.1	2.0

* Production, sales not available for these years.

Source: Sherritt Gordon Mines Ltd. Annual Reports

N.A. — not available.

APPENDIX A4

WORLD SULPHIDE AND LATERITE PRODUCTION STATISTICS

TABLE A4.1

WORLD NICKEL SULPHIDE PRODUCTION

(Content in Ores and Concentrates)

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
	'000 Metric tons													
Canada	87.1	107.6	119.5	116.7	112.2	125.1	127.5	130.4	146.3	158.7	161.9	170.5	126.6	169.2
of which Ontario	87.1	107.6	119.5	116.7	112.2	125.1	127.5	130.4	143.3	146.2	152.0	160.9	115.3	157.8
Australia														
South Africa	—	0.5	0.5	0.6	0.8	1.1	1.3	1.7	1.9	2.4	3.3	3.2	1.2	2.6
Rhodesia	—	—	–	—	—	—	—	—	—	—	—	0.1	—	—
Botswana														
Finland	0.6	0.5	0.2	0.1	0.4	0.1	0.4	0.2	0.1	0.1	0.2*	0.1*	0.1*	0.3
Other	—	—	—	—	—	—	0.2	0.1	0.1	0.1	0.1	—	0.2	0.2
Total	87.7	108.6	120.2	117.4	113.4	126.3	129.4	132.4	148.4	161.3	165.5	173.9	128.7	172.3
USSR	16.0E	16.0	17.5	25.0	29.0	33.0	37.0	40.0	42.0	44.0	47.0	50.0	53.0	53.0

* Content of nickel sulfate.

TABLE A4.1 (continued)

WORLD NICKEL SULPHIDE PRODUCTION

(Content in Ores and Concentrates)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
	'000 Metric tons																
Canada	194.6	211.4	210.7	196.9	207.3	235.1	202.9	225.6	239.8	193.8	277.5	267.0	235.0	249.0	269.1	242.0	275.0
of which Ontario	182.9	178.0	151.1	135.3	147.0	173.5	145.3	172.4	184.8	133.2	203.4	195.7	171.8	178.4	209.1	180.9	NA
Australia								2.6	4.7	11.2	29.8	35.5	35.5	40.1	46.0	68.3	64.4
South Africa	2.9	2.6	3.5	3.5	4.0	5.2	5.4	5.7	7.5	9.0	11.6	12.8	11.7	19.4	22.1	20.8	22.3
Rhodesia		0.1	0.1	0.1	0.2	0.7	0.7	0.4	1.0	4.0	5.0	11.6	12.0	11.8	12.0	10.0	10.0
Botswana														0.5	3.6	5.4	10.0E
Finland	2.1	2.0	2.4	2.0	3.2	3.0	2.9	3.4	3.2	3.6	5.0	3.5	5.2	5.8	6.0	5.7	6.5F
Other (principally Morocco & Norway)	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.6	0.7	0.5E	0.5E	0.5F
Total (excluding countries with centrally Planned Economies)	199.9	216.4	217.0	203.7	215.0	244.4	212.3	238.1	256.7	222.1	329.3	330.8	300.0	327.3	359.3	358.3	388.7E
USSR+	58.0	75.0	80.0	80.0	80.0	80.0	85.0	95.0	103.0	105.0	110.0	110.0	125.0	135.0	145.0	152.0	175.0E

\+ — Sulphide & laterite production
E — Estimated by Mineral Resources Branch
NA — Not available

Sources: Metallgesellschaft "Metal Statistics" (1947-75)
U.S.B.M. Minerals Yearbook (Communist Countries, "Other" Countries & Rhodesia 1947-75, All Countries 1946)
World Bureau of Metal Statistics (1976 estimates except as noted)
Statistics Canada (Canadian Production 1946-76)
Company Annual Reports (Finland 1976, Australia 1975 & 1976)
Mining Annual Review (USSR 1972-1976)

TABLE A4.2

WORLD NICKEL LATERITE PRODUCTION

(Content in Ores and Concentrates)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
	'000 Metric tons																
New Caledonia	54.1	53.9	33.7	44.5	58.2	61.2	67.8	82.2	116.1	116.8	138.5	150.9	108.1	115.9	136.8	137.0	140.0
Dominican Republic												0.2	17.4	30.1	30.5	26.9	30.0
Australia																17.0F	19.9F
Greece		—	—	—	—	—	0.1	2.5	4.2	5.6	8.6	10.6	11.3	13.9	15.1	14.8	17.0F
U.S.A.	13.0	10.1	10.2	10.4	11.1	12.3	12.0	13.3	13.7	14.2	13.9	15.5	15.3	16.6	15.1	15.4	15.0F
Indonesia		—	—	—	1.1	2.3	2.6	3.8	5.5	4.9	10.8	14.7	14.1	15.8	16.0	14.6	14.6
Philippines		-	—	—	—	—	—	—	—	—	0.1	0.2	0.4	0.4	0.3	9.5	20.0
Brazil	0.1	0.1	0.5	0.9	1.0	1.0	1.0	1.1	1.2	1.6	2.9	3.2	3.4	2.7	3.0	3.2	3.2
Burma		—	—	—	—	0.1	—	0.1	0.2	0.1	0.1E	0.1		0.1	0.1	0.1	0.1F
Total of Above	**67.2**	**64.1**	**44.4**	**55.8**	**71.4**	**76.9**	**83.5**	**103.0**	**140.9**	**143.2**	**174.9**|	**195.4**	**170.0**	**195.5**	**216.9**	**237.5**	**259.8**
Cuba	14.5	16.5	20.0	22.0	24.1	29.1	27.9	34.9	37.3	37.0	36.8	36.5	36.8	36.5	33.9	36.6	40.0
Albania		—	—	NA	3.5	4.0	4.0	4.0	4.1	4.1	5.4	6.0	6.0	5.8	5.6	6.5	7.0
Other Eastern Countries	NA	NA	NA	NA	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	0.2F

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
	'000 Metric tons													
New Caledonia	2.5	2.9	3.6	2.5	4.3	6.7	10.7	17.1	13.7	24.7	29.5	43.3	14.2	32.8
Greece											0.6	1.0	0.3	
U.S.A.	0.3	0.5	0.7	0.7	0.8	0.7	0.6	0.5	0.8	3.5	6.1	9.1	10.7	10.5
Brazil												0.1	0.1	0.1
Total of Above	**2.8**	**3.4**	**4.3**	**3.2**	**5.1**	**7.4**	**11.3**	**17.6**	**14.5**	**28.2**	**36.2**	**53.5**	**25.3**	**43.4**
Cuba*	NA	2.0	—	—	—	—	8.1	12.6	13.2	13.8	14.6	20.2	17.9	17.8

Notes: I Estimates by Mineral Resources Branch
NA Not available
* Other Eastern not available except in total production (Table 2.1.3)

Sources: Metallgesellschaft "Metal Statistics" (1947-76)
U.S. Minerals Yearbook (1946)
World Bureau of Metal Statistics (1976 Estimates)
Annual Reports (Australia 1975 & 1976)

TABLE A4.3

WORLD NICKEL MINE PRODUCTION (ALL SOURCES)

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
	'000 Metric tons															
Western World	280.5	261.4	259.5	286.4	321.3	295.8	341.1	397.6	365.3	510.2	526.2	470.0	522.6	576.2	595.8	648.5
Other*	95.3	104.0	106.0	110.2	115.7	119.9	137.0	147.6	149.3	155.7	156.0	171.4	181.5	189.3	199.7	222.0
	375.8	365.4	365.5	396.6	437.0	415.7	478.1	545.2	514.1	665.9	682.2	641.4	704.1	765.5	795.5	870.5

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	'000 Metric tons														
Western World	90.5	112.0	124.5	120.6	118.5	133.7	140.7	150.0	162.9	189.5	201.7	227.4	153.4	215.7	267.1
Other*	NA	18.2	17.8	25.4	29.6	33.7	45.9	53.6	56.2	58.9	63.1	71.8	73.2	73.8	76.3
	NA	130.2	142.3	146.0	148.1	167.4	186.6	203.6	219.1	248.4	264.8	299.2	226.6	289.5	343.4

* Includes Cuba, USSR, Germany (DR), Albania, Poland plus other Eastern countries with centrally planned economies.

Source: Metallgesellschaft "Metal Statistics" (1947-75)
U.S. Minerals Yearbook (1946)
World Bureau of Metal Statistics (1976 Estimates)
Annual Reports (Australia 1975 & 1976)

APPENDIX A5

SALIENT U.S. NICKEL STATISTICS

TABLE A5.1

U.S. NICKEL IMPORTS BY COUNTRY OF ORIGIN

(Nickel Content to nearest 100 metric tons)*

Year	Month	Canada	French Pacific Islands	Norway	Dominican Republic	Australia	Philippines	South Africa	U.S.S.R.	Botswana	Other	TOTAL
1974	Total	116,800	15,800	15,100	17,000	5,300	—	3,600	10,200	—	17,000	200,900
1975	Total	90,700	16,600	10,300	7,500	5,100	4,100	3,400	3,400	—	6,100	147,200
1976	January	4,200	—	1,200	700	500	100	300	—	600	800	8,400
	February	5,100	—	300	400	600	600	300	—	300	500	8,000
	March	9,300	700	1,300	1,500	200	1,500	300	—	—	500	15,300
	April	7,200	100	1,500	1,400	100	1,300	100	—	500	600	12,600
	May	7,700	600	1,100	300	300	—	500	—	—	500	11,000
	June	9,500	3,300	1,200	300	100	100	500	1,100	700	400	17,200
	July	6,900	—	1,000	100	600	800	400	—	—	300	10,100
	August	7,700	—	1,000	100	800	1,500	500	—	1,900	400	13,900
	September	11,700	2,600	1,300	100	500	1,200	400	—	1,700	1,300	20,700
	October	8,200	—	900	2,200	400	—	1,500	—	1,200	300	14,600
	November	8,200	800	1,100	800	1,000	300	200	—	—	500	12,800
	December	13,400	—	1,300	2,500	—	200	500	—	3,000	1,500	22,400
1976	Total	99,100	8,200	13,000	10,300	5,100	7,400	5,400	1,100	9,900	7,400	167,000
1977	9 months	59,300	14,500	13,900	9,600	4,100	8,600	4,400	1,300	7,900	8,300	131,900

* Monthly totals do not necessarily equal annual totals due to rounding (average error = 2%)

Source: U.S. Bureau of Mines.

TABLE A5.2

UNITED STATES NICKEL PRODUCTION

	REFINED PRODUCTION		MINE PRODUCTION	
	Primary[1]	By-Product[2]	Total Mine Production	Hanna Refined Production
	Metric tons			
1976	30,800E	800E	15,000E	11,900
1975	19,900	800E	15,000E	11,800
1974	12,600	800	15,100	11,900
1973	12,600	900	16,600	11,700
1972	14,300	2,300	15,300	11,900
1971	14,200	2,300	15,500	11,900
1970	14,100	2,600	14,500	11,800
1969	14,300	2,500	15,500	12,000
1968	14,800	1,800	15,700	11,600
1967	13,300	1,400	13,900	11,200
1966	12,400	900	13,600	10,400
1965	12,600	800	14,700	10,600
1964	11,500	900	14,000	9,700
1963	10,800	600	12,200	9,100
1962	10,600	600	11,900	8,900
1961	10,500	600	11,900	8,800
1960	12,200	800	12,800	10,100
1959	36,300[3]	400	12,100	9,400
1958	36,200[3]	500	12,200	9,600
1957	45,700[3]	500	11,700	N.A.

NOTES:

E — estimates by Mineral Resources Branch.

1. Primary nickel plus nickel contained in ferronickel, nickel oxide sinter and monel metal smelted directly from ores.
2. By-product of other metal refining (mainly nickel salts from copper refining).
3. Mine Production in U.S.A. and nickel in matte and oxides exported; includes Cuban operations expropriated in 1960.

Sources: U.S. Bureau of Mines (By-product and total mine production).
Annual Reports (Hanna).
Metallgesellschaft "Metal Statistics" (Primary refined production)

TABLE A5.3

U.S. CONSUMPTION OF PRIMARY NICKEL
(All Forms)
(Metric tons)

1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
150,700E	136,000	194,500	182,100	156,900	133,200	149,100	136,600	144,500	157,700
1966	**1965**	**1964**	**1963**	**1962**	**1961**	**1960**	**1959**	**1958**	**1957**
170,400	156,100	133,300	112,900	107,700	107,500	98,100	102,200	71,700	111,100
1956	**1955**	**1954**	**1953**	**1952**	**1951**	**1950**	**1949**	**1948**	**1947**
115,700	99,900	85,900	95,900	92,000	78,600	90,700	62,000	84,900	73,300

Sources: Metallgesellschaft
Mineral Resources Branch Estimate.

TABLE A.5.4

U.S. PRIMARY NICKEL CONSUMPTION

1976

BY INTERMEDIATE AND END USE

	Metric tons	% of Total Reported
Steel		
Stainless & heat resisting	39,905	29.92
Alloys	16,471	12.35
Superalloys	7,014	5.26
Nickel-copper & copper-nickel alloys	5,908	4.43
Permanent magnet alloys	5,223	3.92
Other nickel & nickel alloys	27,931	20.94
Cast irons	2,306	1.73
Electroplating	24,330	18.24
Chemicals & chemical uses	1,029	0.77
Other uses	3,255	2.44
Total reported	133,255	100.00
Total all companies (calculated)	152,774	

BY RAW MATERIAL

Nickel unwrought	85,580	64.17
Ferronickel	27,180	20.37
Nickel oxide	18,393	13.78
Nickel salts	847	0.65
Other forms	1,370	1.03
Total reported	133,371	100.00

Source: U.S. Bureau of Mines.

TABLE A.5.5

TRENDS IN U.S. NICKEL INTERMEDIATE AND END USE

	1972-1976	1974-1975	1975-1976
	..... % per annum		
Stainless and Heat Resisting Steel	- 0.6	-50.5	+29.6
Alloy Steel	- 1.5	-13.2	- 6.3
Superalloys	- 9.7	-48.7	+36.0
Nickel-Copper & Copper-nickel alloys	- 5.6	0.0	-24.0
Permanent magnet alloys	+ 6.5	-38.1	+76.5
Other nickel and nickel alloys	+ 1.3	-15.7	-14.8
Cast irons	-11.8	-17.6	- 8.6
Electroplating	- 1.6	-28.3	+46.2
Chemicals & Chemical uses	- 0.8	+46.9	+30.9
Other uses	-10.1	-20.1	- 3.6

Source: U.S. Bureau of Mines.

TABLE A.5.6

U.S. CONSUMPTION BY END USE INDUSTRY

	1964 (Metric Tons)	%	1974 (Metric Tons)	%
Chemicals	9.5	5.7	36.0	15.1
Petroleum	5.3	3.2	21.5	9.0
Fabricated metal products	14.3	8.6	24.0	10.0
Transportation:				
Aircraft and parts	13.2	8.0	16.7	7.0
Motor Vehicles and equipment	24.7	14.9	26.3	11.0
Ship and boat building and repairs	4.8	2.9	7.3	3.1
Electrical	15.4	9.3	31.0	13.0
Household appliances	15.3	9.2	16.7	7.0
Machinery	19.6	11.8	16.7	7.0
Construction	6.2	3.7	21.5	9.0
Other	37.7	22.7	21.4	9.0
TOTAL	166.0	100.0	239.1	100.1

Source: U.S. Bureau of Mines.

TABLE A.5.7

U.S. CONSUMER STOCKS

MONTHLY AVERAGES

YEAR	MONTH	NICKEL UNWROUGHT	FERRO-NICKEL	NICKEL-OXIDE	OTHER	TOTAL
				Metric Tons		
1977	January	13,603	6,530	4,378	628	25,121
	February	15,043	7,878	4,925	539	28,384
1976	January	13,080	8,210	2,782	543	24,615
	February	11,560	7,604	2,726	515	22,405
	March	10,760	6,648	3,017	508	20,933
	April	9,883	6,779	2,951	395	20,008
	May	9,572	6,378	2,682	467	19,099
	June	9,291	6,057	3,091	649	19,089
	July	10,241	5,286	3,004	741	19,272
	August	10,800	4,728	2,898	710	19,137
	September	11,268	3,818	4,123	565	19,773
	October	12,784	4,156	3,957	550	21,446
	November	13,363	5,268	3,669	588	22,888
	December	13,344	5,915	3,664	552	23,445
1975	January	22,481	9,836	4,682	1,010	38,007
	February	22,326	10,748	4,315	810	38,199
	March	20,821	9,827	3,887	852	35,387
	April	21,983	9,913	3,380	904	36,180
	May	21,355	10,187	3,147	1,017	35,706
	June	24,281	9,688	3,777	870	38,616
	July	24,205	11,622	4,189	830	40,845
	August	22,734	11,734	3,808	724	39,000
	September	21,270	11,251	3,331	646	36,498
	October	20,776	10,829	2,875	639	35,118
	November	17,384	10,359	2,870	603	31,215
	December	14,601	9,994	2,565	521	27,680

ANNUAL AVERAGES

1974		41,088
1973		26,090
1972		23,822
1971		14,520
1970		22,415
1969		15,036
1968		24,917
1967		28,038
1966		30,198
1965		12,743
1964		15,590
1963		15,595
1962		12,202
1961		16,600
1960		10,314
1959		12,814
1958		12,101
1957		22,936

Source: U.S.B.M.

TABLE A.5.8

COMPARISON OF U.S. CONSUMPTION AND INVENTORY LEVELS

YEAR	CONSUMPTION[1]	DECEMBER CONSUMER INVENTORIES[2]	INVENTORIES/ CONSUMPTION
	metric tons		
1976	50,700E	23,446	0.156
1975	36,000	27,680	.203
1974	94,500	41,088	.211
1973	82,100	26,090	.143
1972	56,900	23,822	.152
1971	33,200	14,520	.109
1970	149,100	22,415	.150
1969	136,600	15,036	.110
1968	144,500	24,917	.172
1967	157,700	28,038	.178
1966	170,400	30,199	.177
1965	156,100	12,743	.082
1964	133,300	15,590	.117
1963	112,900	15,596	.138
1962	107,700	12,202	.113
1961	107,500	16,600	.154
1960	98,100	10,314	.105
1959	102,200	12,814	.125
1958	71,700	12,101	.169
1957	111,100	22,936	.206
		Average	0.148

Sources: (1) Metallgesellschaft.
(2) U.S. Bureau of Mines.

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